ED 2002-135
16 June 1967

APOLLO APPLICATIONS PROGRAM (AAP)
PAYLOAD INTEGRATION

Technical Study and Analysis Report

Determination of Simulator Requirements
and Evaluation of an Alternate Test Program for
AAP 1/2/3/4

Contract No. NAS8-21004

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FOREWORD

This document is submitted in accordance with the requirements of DRL Line Item 20 of Exhibit C of Contract No. NAS8-21004. This is the one hundred and thirty fifth trade study and analysis report submitted under this line item number.

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1. INTRODUCTION

1.1 Purpose - It has been recognized that factors such as cost, schedules and lack of prototype availability may preclude the performance of cluster type design verification testing. The purpose of this report is to present the results of a study performed to evaluate the effectiveness of a test program for AAP 1/2/3/4 which does not include a cluster test and to determine the gross simulation requirements for such a program.

1.2 Scope - This report establishes a test program for AAP 1/2 and AAP 3/4 based on the specific ground rules identified in section 1.5. Gross simulation requirements are identified by geographic area and the complexity of the simulators are described in broad terms.

Utilizing the prototypes assumed to be available in each area and the simulators established during the study, the test program's effectiveness has been evaluated.

The ability of the contractors to adequately qualify and and verify the design of individual carriers is not the basic concern of this study. The study is primarily concerned with the capability of the defined test programs to verify inter-carrier and cluster systems design compatibility.

1.3 Reference Documents

Contractor Documents

RD 200000	Performance and Design Requirements, Orbital Workshop/Apollo Telescope Mount, Rev. 1, SCN 1, 15 February 1967
MD-80-0018	General Interface Schematics, AAP 1 through 4, On Orbit Configuration, 3 February 1967

NASA Documents

M-D ML 3200-055	Program Directive No. 3A, Flight Mission Directive for AAP 1/ AAP 2

M-D ML 3200.059	Program Directive No. 5, Flight Mission Directive for AAP 3/AAP 4, National Aeronautics and Space Administration
50M02410	General Test Plan for Apollo Telescope Mount Project, 1 May 1967, National Aeronautics and Space Administration
	Apollo Applications Test Requirements, Coordination draft (not approved), 28 April 1967, National Aeronautics and Space Administration

1.4 Terminology Definition

In order to better understand the study results presented in this report, some of the more significant terms have been defined. Due to the specific purpose of this study, many of the definitions apply only to their use in this study and may not agree with the universally accepted meaning of the term.

1.4.1 Hardware and Test Specimen Definitions

a. Flight hardware or flight carrier - In general, this applies to hardware fabricated to firm design specifications, and intended for operational (flight) usage. Normally, this hardware is built and tested after the design has been environmentally qualified and functionally confirmed. The exceptions on this study are the AM and MDA which will not have design verification flight configured prototypes (non-functional structural prototypes will be provisioned for qualification tests) consequently some design verification testing will be performed on the flight carriers.

b. Prototypes - Unless other specified, this term means a fully flight configured article using the identical components, layout and mounting provisions as the flight hardware. On existing prototypes, the systems which have not been modified for the AAP program and do not directly interface with AAP mods need not be complete unless they are required to support test. Structural proto or structural model refers to a completely flight configured structure with no functional components.

c. Simulators - Three types of simulation are used in this study:

1) Functional simulators- Unless noted otherwise, the term "simulator" refers to a functional simulator which will simulate the interface input and output dynamic characteristics of the article being simulated. Physical properties are not representative of the article being simulated (size, shape, etc.). The degree to which the simulator represents the simulated article will vary and is further defined in Appendix A.

2) Mockups - The mockup will simulate the phyical properties of the article being simulated in terms of size, shape, dimensions, layout, etc. Mockups do not have functional components and are used in this study mainly for fit, clearance and layout verification.

3) Master gauge simulation - This type of simulation provides for simulation of some of the physical properties, especially at the interfacing point, but not necessarily all of the physical properties of the article being simulated. The radiator gauge used at MSFC, for example, requires precision dimensions, hole patterns, and sealing technique at the AM-MDA interface point, but is not necessarily representative of the radiator outboard profile, weight, C.G., etc.

1.4.2 Test Configurations

a. Individual carrier tests are those tests performed on single CEI carriers. Although interfacing carriers may be simulated to facilitate valid test results, no two carriers are mated, either physically or functionally, in this category.

b. Inter-carrier tests as used in this study refers to compatibility testing of the configurations achieved during launch configuration or between two major carriers. For example, verification of compatibility between the CSM 1 and the LM A/S in the docked configuration is treated as an inter-carrier test requirement.

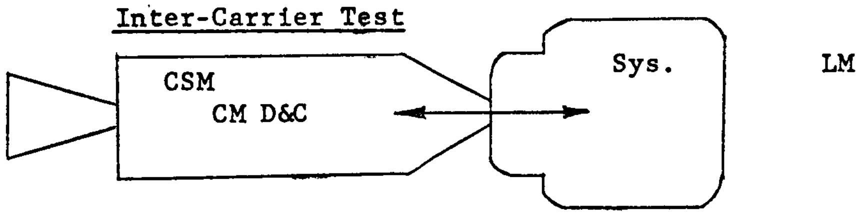
c. Cluster test requirement refers to compatibility testing of three or more major carriers and the cluster systems created by the mating of these carriers.

To further clarify these three test configuration definitions, refer to the examples provided in the sketch below:

Individual Carrier Test

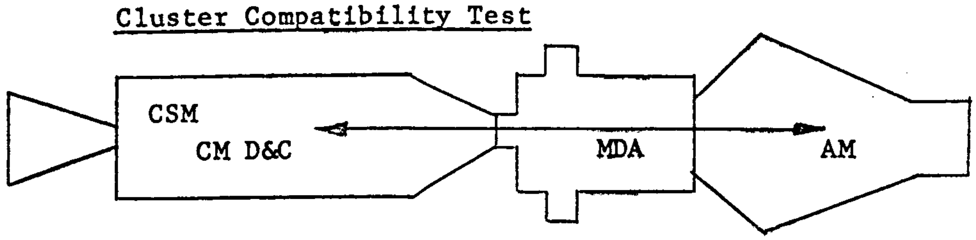
example: checkout of the CSM display and control system

Inter-Carrier Test



example: verify CSM to LM display and control compatibility

Cluster Compatibility Test



example: verify cluster compatibility of CM to AM display and control

1.4.3 Test Categories

a. Development testing as used in this study refers to the test activities performed to obtain data to assist in the development of the design, to evaluate suitability of materials and components to mission environments, and to establish some level of confidence in the selected design prior to committing the design to a costly formal qualification program.

b. Qualification as used in this study is considered to be an individual carrier test activity limited solely to environmental qualification. Functional design verification under ambient environments is considered a design verification test as described under item "d" below.

In this study, no qualification testing is accomplished at an assembly level higher than the CEI carrier. The term "dynamic testing" is not used in this study, since it is not a separate test category, but is in fact induced environment testing and accordingly is considered as part of environmental qualification.

c. Acceptance testing is the functional test activity performed to prove that the flight hardware has been fabricated to design drawings, using approved processes and techniques and that the CEI performs in accordance with design specification. It is not the objective of acceptance testing to prove the validity and adequacy of the selected design, but rather to prove that the hardware has been built to that design. In general, acceptance testing at the CEI carrier level is performed under ambient environments, however, in some cases vibration testing at less than qualification level and thermal vacuum testing may be included in the acceptance test activity. Since acceptance testing is performed on flight hardware exclusively, potential detrimental tests are not performed.

d. Design verification testing is that test activity which is performed to verify or confirm the adequacy of the selected design. As used in this study, all design verification testing is performed under ambient environments. Environmental testing, which is in reality a part of design verification, is performed under qualification testing. Within this broad category, three sub-categories of design verification testing are used:

1) Individual carrier design verification is that activity associated with a single carrier. Usually this test activity is performed with interface simulation and does not prove interface design compatibility, but does prove the design of the individual carrier.

2) Inter-carrier design compatibility verification is the test activity performed to prove compatibility between two carriers within the meaning of "inter-carrier" as described previously.

3) Cluster design compatibility verification is that activity performed to prove cluster system design compatibility involving three or more carriers which when mated form cluster systems across the physical interfaces.

e. Prelaunch checkout is that test activity which is performed at KSC to verify that the flight hardware is ready for flight. Generally, this activity consists of location change checkout of carriers which have just been subjected to extensive acceptance testing at the contractor facility. Accordingly, prelaunch checkout is usually less comprehensive than acceptance testing, and yet complete enough to establish confidence that system performances have not been degraded by pack and ship, transportation and storage.

In some instances where two carriers are mated for the first time at KSC, the prelaunch checkout activity is more comprenehsive.

Due to the nature of the ground rules established for this study, many more first-time mating activities occur at KSC than would normally be anticipated.

1.4.4 Test Types

a. An integrity test is an in-process test performed during assembly to assure the article is constructed or assembled to design specifications. Tests include: Proof pressure testing, electrical short and ground testing and leak testing.

b. A functional test is a test of the system's performance under an ambient environment.

c. An environmental test is a test performed under simulated environmental conditions and may be performed with the test specimen operating or static depending on the objectives.

d. A parametric test is a test performed during design verification testing under off-nominal operational conditions to evaluate the system's performance under abnormal condition. Parametric testing in excess of design limits is usually considered "off-limits" testing.

e. An off-limits or design margin test is a design verification or qualification test under conditions more severe than those for which the hardware was designed to withstand. These conditions may be increased environmental levels, increased exposure durations, increased cycles or system parametrics in excess of design limit. Off-limits testing is generally used to verify calculated design safety margins and may be destructive in nature.

f. A mission simulation is a functional test of a carrier, inter-carrier or cluster in which the exact mission sequence is performed in compressed time. As an objective, all systems are energized and operated in the modes in which they would operate on orbit. This is usually a manned test.

g. A contingency and FMECA validation is a series of tests which are performed on prototype hardware to verify that contingency planning is feasible and could be implemented if required during an on orbit malfunction or emergency. A secondary objective of this type of testing is the validation of failure mode effects analysis. Since this type of test activity involves simulation of failures in order to evaluate secondary failures and cumulative effects, the testing could be detrimental and is not performed on flight hardware.

1.5 Ground Rules - In performing this analysis, certain ground rules were provided by NASA, and other ground rules evolved as the study progressed. Major ground rules were coordinated with NASA and approved as a basis for performing this study.

In order to maintain consistency throughout the study, ground rules were rigidly adhered to, although in some cases application of other ground rules might provide a more logical test program. Manipulating the ground rules to fit specific cases would have increased the complexity of the study which would have prevented completing the study within the allotted time.

1.5.1 As a basis for departure, it is assumed that all carriers, carrier modifications, add-on subsystems and experiments will be individually qualified and checked out. Functional performance of the individual carriers is not the concern of this study, but rather the ability to verify compatibility of the carriers/experiments in a cluster configuration without actually performing a ground cluster test.

1.5.2 With the exceptions noted below, performance requirements are based on the "Performance and Design Requirements, Orbital Workshop/Apollo Telescope Mount", Rev. 1, SCN 1, dated 2-15-67, MMC Report RS 200,000. Interfaces are based on the "General Interface Schematics, AAP 1 through 4, On Orbit Configuration", MD-80-0018, dated 2-3-67.

Exceptions:

a. The resupply function is not achieved through use of a separate module but is provided by modification to a sector of the Flight 3 SM. Resupply transfer is accomplished by external SM to AM umbilicals.

b. The LM&SS will be flown on a separate flight (other than AAP 1-4) and will not form part of the cluster.

c. The IU of Flight 3 will carry S027 experiment and will interface with the CM via the SLA and SM (display and control of S027 in CM).

d. The Flight 4 IU experiments will not have any interfaces with other modules (control from the ground via uplink and data transmission by IU system to ground station).

e. Solar panels are hinged off the S-IVB and are not part of the SLA.

f. The following experiments are stored in the MDA at lift off and operated on orbit in locations shown below. Reactivated experiment loads are considered in the simulator requirements for flight 3/4 checkout.

D018	OWS	
D019	OWS	
D020	OWS	
D022	OWS	
M018	OWS	
M050	OWS	
M051	OWS	Reactivated Flight 3/4
M052	OWS/CM	
M053	OWS	
M479	MDA	
M508	OWS	Activated for first time
M509	OWS	on Flight 3 & 4
T020	OWS	
M488	MDA	
M489	MDA	
M492	MDA	
M493	MDA	
S009	MDA ext.	
S018	MDA	
S019	MDA	
S063	MDA	Reactivated Flight 3/4
S069	MDA	
S070	MDA	
T004	MDA	
S065	MDA	Reactivated
M055	MDA	

1.5.3 It is assumed in this study that CSM modification from standard block II to AAP configuration is performed by NAA and not a separate contractor.

1.5.4 Maximum testing will be performed at the carrier contractor's facility.

1.5.5 Maximum utilization will be made of the KSC flight hardware test program to demonstrate experiment module interfaces consistent with flight schedule constraints and hardware availability.

1.5.6 Only existing or proposed carriers, either assumed or known to be available, were utilized for this test program. No additional prototypes or flight carriers were created for test articles.

1.5.7 Carrier interface design verification test requirements cannot be satisfied without mating either two prototypes or flight articles. Simulators, at best, will only verify to a limited degree, the carrier interface design verification test requirements.

1.5.8 The test programs on the component and subsystem level will be increased over that which would be required for the cluster test program to supplement the analysis of cluster system compatibility with trend data, qualification data, overstress and design margin data, etc.

1.5.9 There will be no complete flight or flight configured prototype experiment modules shipped between centers or contractors.

1.5.10 There will be no flight configured prototype test articles at KSC.

1.5.11 There will be no experiment integration into carriers at KSC with the exception of late arriving or time sensitive experiments. All experiments integration will be accomplished at the contractor's facility prior to shipment to KSC.

1.5.12 In this study, the S-IVB is not prewired. The cable harness is stored in the AM and carried into the LH_2 tank after passivation.

1.5.13 The solar array is stored in pods on the side of the S-IVB and deployed from these pods.

1.6 Philosophies - The basic philosophy utilized for this test program was to verify, to the maximum extent possible, the experiment module interfaces and cluster system compatibility without a cluster test program.

All locations where the flight and prototype experiment modules were assumed to be available for testing were evaluated to determine the best test program utilizing available hardware. After preparation of a basic test program, the simulator requirements at each location were determined.

In developing the test programs, the following general philosophies were formulated:

1.6.1 Utilize the cluster non-functional mockup to a greater extent to determine mechanical interface problems and man-machine compatibility.

1.6.2 Make the integration and prelaunch test program at KSC more comprehensive to include limited systems interface design verification testing.

1.6.3 Utilize the results of individual module tests with extensive analyses to decrease the risk of cluster systems incompatibility in orbit.

1.6.4 Analyze the results of the test program performed on each individual carrier to determine interface conditions that were not predicted by analysis. These conditions will be evaluated and test requirements imposed on the interfacing carrier, as required, to demonstrate carrier systems compatibility with the new interface requirements.

1.6.5 The following philosophies were established with respect to the use of simulators.

a. The center or contractor requiring a simulator for carrier design verification, qualification testing, and acceptance testing will be responsible for design and build of the simulator in accordance with the requirements of the carrier interface design specifications. These simulators will be referred to as Design Specification Interface (DSI) simulators.

b. The center or contractor responsible for providing the flight carrier or experiment will be responsible for the design and build of the more complex simulators for their carrier or experiment required for semi-cluster test activities at KSC. These simulators will be referred to as carrier simulators.

c. Upon creation of a carrier simulator, the center/contractor will integrate the simulator into the flight hardware configuration control system in such a manner as to prevent the release of flight hardware engineering changes without the release of either a simulator change or a positive statement that a change is not required.

d. After delivery of the carrier simulator to the using agency, the configuration of the simulator will be maintained as follows:

- The carrier contractor who built the simulator will be responsible for maintaining the configuration engineering. Engineering changes will be forwarded to the user.

- Using agency will physically install the modification kits provided by the carrier contractor who is responsible for the simulator. PM and spares will be the responsibility of the using agency.

- Improvement changes initiated by the user or simulator design incompatibilities involving the simulator will be processed through a liaison system provided by the simulator contractor.

e. The carrier interface design verification test requirements cannot be satisfied by utilizing a simulator, but requires the two interfacing carriers. The simulator cannot simulate the interface to the degree required to find unexpected incompatibilities that were not determined by analysis. Therefore, the confidence that the module interfaces will be compatible in orbit, utilizing simulators, is relatively low.

1.6.6 The following test philosophies will be imposed on the individual experiment module test program to demonstrate an adequate safety margin of the carrier interfacing systems and to provide a higher level of confidence that the interfacing systems can meet the cluster level test objectives.

a. EMC Testing - Perform susceptibility tests at the integrated experiment carrier level. Verify that the critical circuits have an adequate safety margin when the injected energy is above predicted levels. Perform a module radiation (EMC) test to verify the values that are required for EMC test of the other cluster carriers.

b. Cluster System/Experiment Compatibility - By the use of interface simulators (DSI), simulate the operational levels of the interfacing carrier subsystems that would represent the conditions imposed by operation of the simulated experiments. Exceed these levels on critical systems to verify an adequate safety margin.

c. Cluster Systems Parametric Variations - By the use of interface simulators (DSI), simulate the operational limits of the interfacing carrier subsystems. Exceed these levels on critical systems to verify an adequate safety margin.

d. Real Time Mission Simulation - Test each carrier individually, starting with the carrier suspected of having the problem. Evaluate the test results and use analysis to determine the effect on the carrier electrical and mechanical interfaces. Impose these conditions on the interfacing carrier, utilizing simulators.

e. Contingency Planning Verification and FMECA Validation - Simulate failures in the cluster systems through use of a prototype or flight carrier and interface simulators. Use analysis to determine failure effect on all interfacing carrier subsystems and impose these conditions on the interfacing modules.

2. FLIGHT 1/2 TEST PROGRAM

2.1 Test Program Description - The test program described in this section is that portion of the total Flight 1 and 2 test program relating to the verification of intercarrier and cluster systems compatibility. The basic test program is shown in the time based test and checkout sequence, figure 1. Figure 1 illustrates the basic testing proposed for the individual qualification and flight carriers and the testing proposed between prototype or flight carriers to verify intercarrier compatibility.

The portion of the Flight 1 and 2 test program that is not described in this report includes carrier development test programs and the subsystem, component, experiment and materials test programs. These programs, with the exception of the cluster system mockup, do not have a significant effect on the verification of the carrier interface. The cluster system mockup will be utilized to verify cluster system physical interfaces, clearances, access, etc. The proposed test program shown in the Flight 1 and 2 Time Based Test and Checkout Sequence has some significant changes over that proposed for the cluster test program. Basically these changes are:

a. The test time at KSC has been extended one month over that proposed for the cluster test program. The specific areas are:

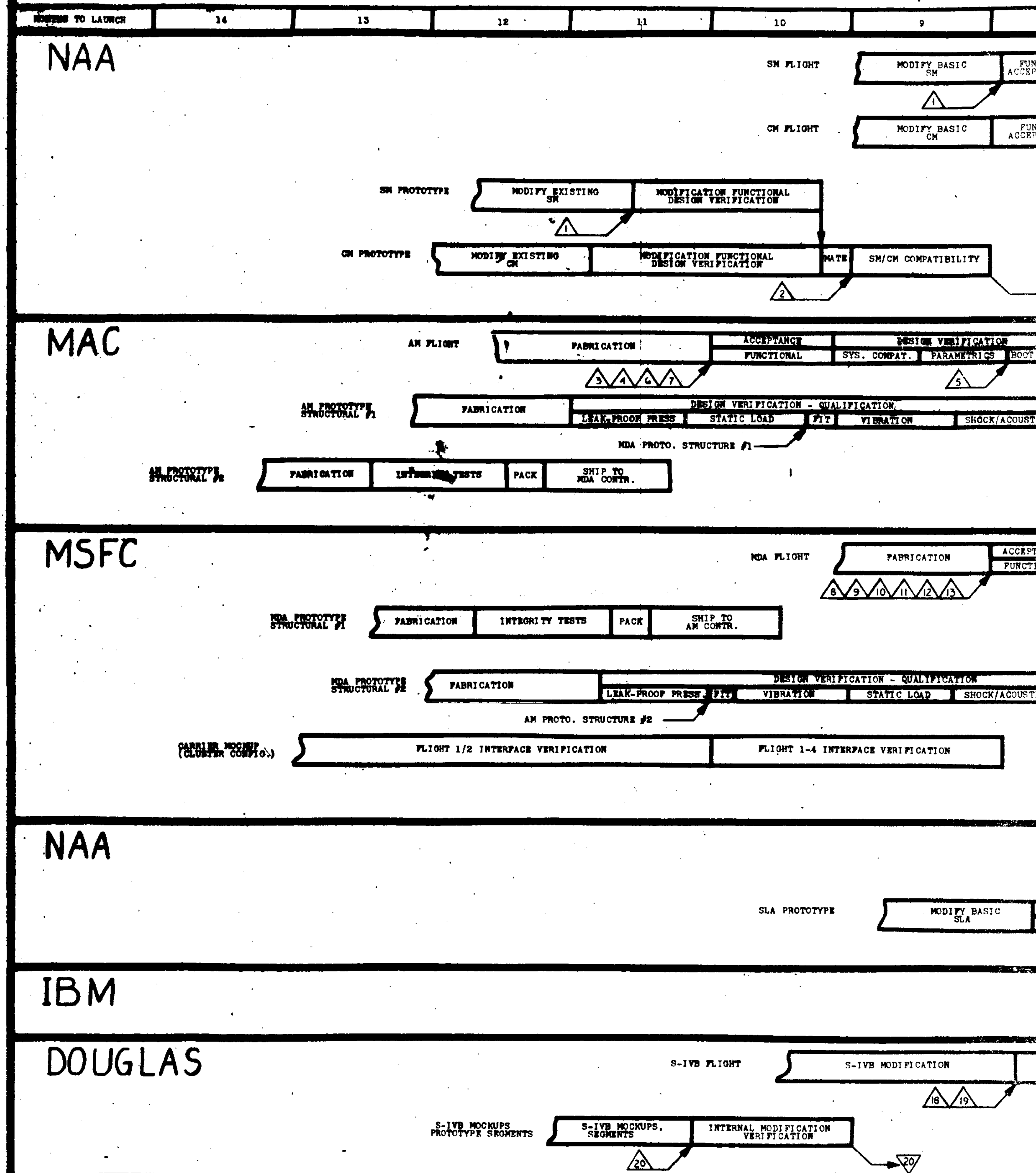
- The AM/MDA space vehicle mate. This test sequence was extended one week to verify the compatibility of the AM, MDA, IU, SLA, and S-IVB in the launch and simulated orbit configuration.

- The cluster type tests involving the CSM, AM, MDA. This test sequence was extended two weeks to verify the cluster systems compatibility. This is the first time that flight configured hardware has been assembled in a partial cluster configuration.

- The compatibility tests of the AM/MDA combination. This functional test was extended one week to verify the compatibility of the AM and MDA. This is the first time the flight configured AM and MDA have been mated.

Fig 1-A 15-A

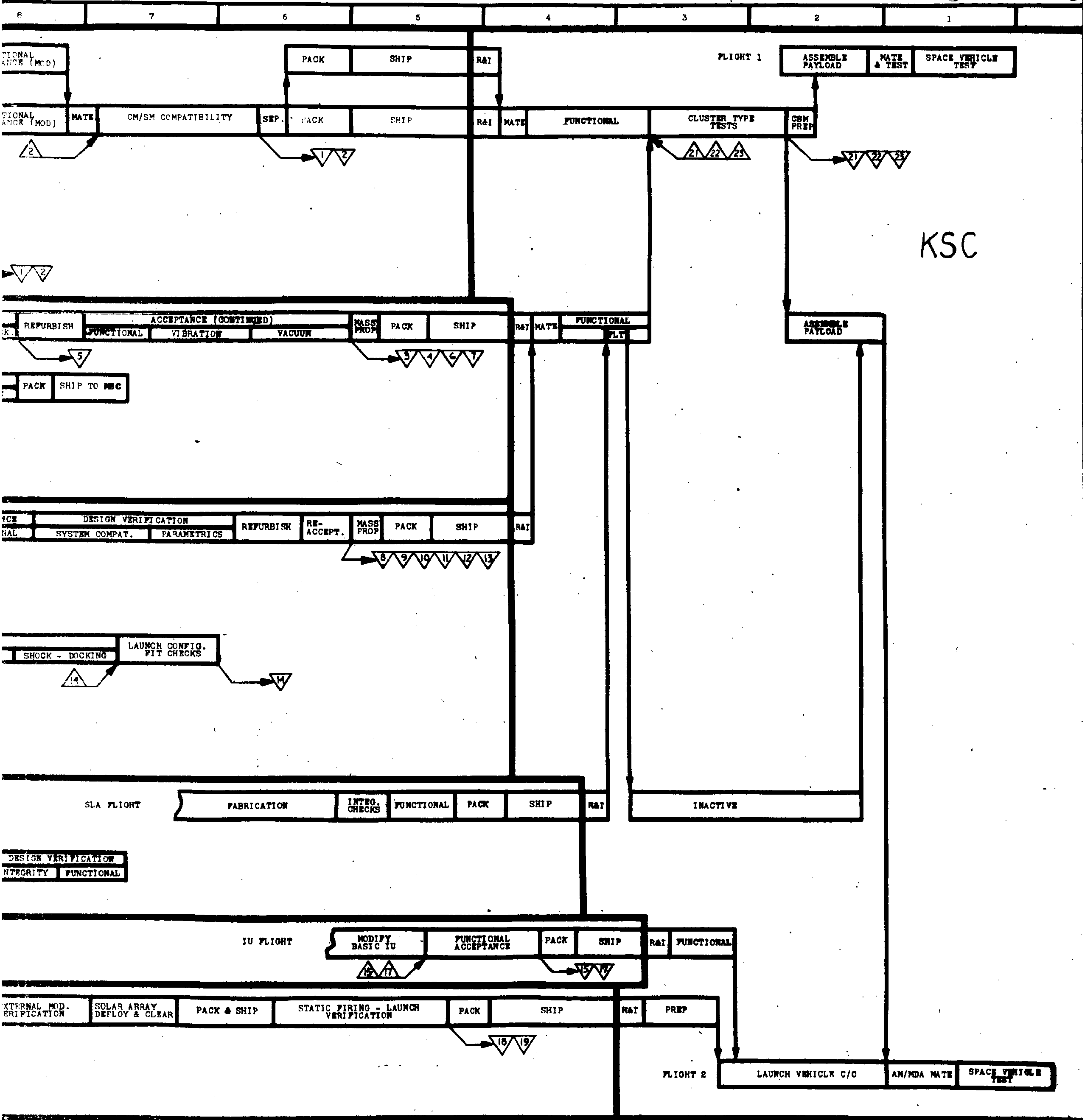
AAP FLIGHT 1&2 TIME BASED TEST AND CHECKOUT SEQUENCE



NOTES:

1. CODE
   - △ - SIMULATOR REQUIRED
   - ▽ - SIMULATOR USAGE COMPLETE
2. THE NUMBER IN THE TRIANGLE REFERS TO A SPECIFIC SIMULATOR ITEM NUMBER. EACH SIMULATOR IS DESCRIBED IN APPENDIX "A" BY ITEM NUMBER.
3. SIMULATOR IDENTIFICATION

1	AM
2	MDA
3	MDA
4	CSM
5	S-IVB FWD. MOCKUP
6	EXPERIMENT SIM.
7	IU PASS. MOD.
8	AM
9	CSM
10	LM A/S
11	EXPERIMENTS
12	DOCKING COLLAR
13	AM RADIATOR
14	AM & IU COMP. MOCKUPS
15	S-IVB PASS. MOD.
16	DELETED
17	AM
18	IU
19	AM



20 EXPERIMENT SIM.

21 LM/ATM

22 IU/S-IVB

23 CSM-3 SIM.

4. ABBREVIATIONS

R&I - RECEIVING & INSPECTION
PREP - PREPARATION
C/O - CHECKOUT
COMPAT - COMPATIBILITY
SEP - SEPARATE
CK - CHECK
SYS - SYSTEM
PROP - PROPERTIES
CONTR - CONTRACTOR
INTEG - INTEGRITY
MOD - MODIFICATION
VERIF - VERIFICATION
PRESS - PRESSURE
CONFIG - CONFIGURATION
PROTO - PROTOTYPE

AAP FLIGHT 1 & 2 TIME BASED TEST AND CHECKOUT SEQUENCE

JUNE 16, 1967

b. The test time for the AM and MDA carriers has been extended due to the series testing required for design verification tests and refurbish time along with the acceptance test utilizing a single article.

The time based test and checkout sequences were derived from the ground rules in section 1.0 of this report and from a technical evaluation of the program requirements. The test programs for the AM and MDA were based on information from MSFC, and CSM test programs were based on previous test programs developed for AEP and the KSC test program was based on the Martin test program proposed during the Phase C Study (Report ED-2002-49).

The time based test and checkout sequence shows the experiment module flow and the major experiment module simulators that are required during each test phase of this flow.

The simulator requirements for each test are indicated by a number enclosed in a triangle. A triangle with an arrow pointing toward the module test flow indicates that the simulator is required during the test sequence(s) until another arrow leaves this test flow and points to a triangle with the same number. This indicates that the simulator usage is no longer required. The number in the triangle refers to a specific simulator item number. Each simulator is described in Appendix A by this item number.

The simulator requirement summary, figure 3, defines the requirement for each experiment simulator and identifies the test requirement that is satisfied by the test involving this simulator.

The basic experiment module test sequence was derived by determination of the acceptance test duration and sequence and using the ground rule that each specific qualification or design verification test must be demonstrated before a similar acceptance test could be completed.

An arrow at the end of a test sequence indicates that the carrier is moved to be mated with other carriers either for test or assembly.

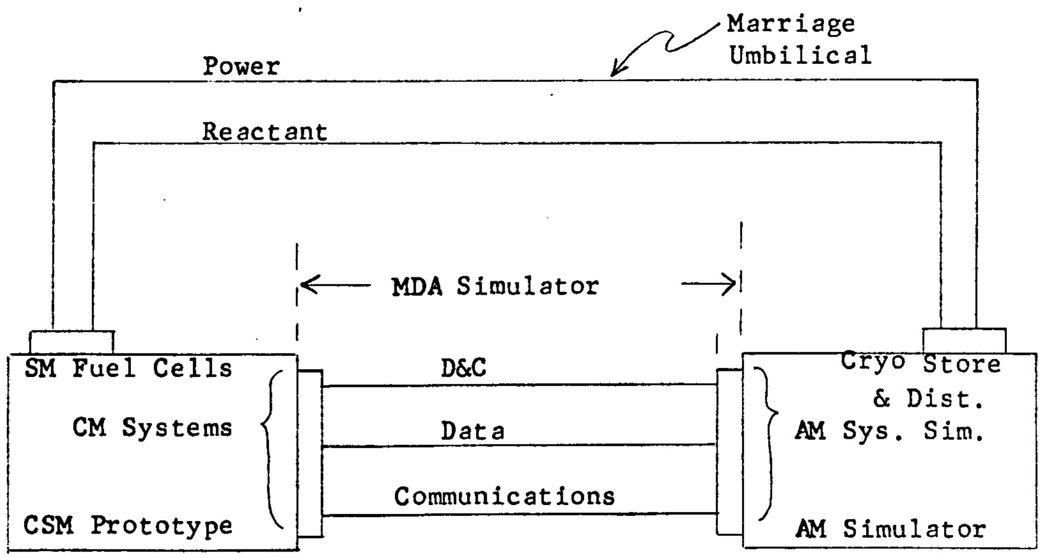
The basic carriers shown in the AAP Flight 1 and 2 Time Based Test and Checkout Sequence have the following configurations:

Test Article	Description
1. SM & CM Prototype	These prototypes are modified to have the full Flight 1 configuration.
2. SM & CM Flight	These articles have a Flight 1 configuration.
3. AM Prototype - Structure #2	This prototype structural article has a full Flight 2 structural configuration, capable of structural pressure integrity and dynamic testing to qualification levels. This structure article will have the proper interface to allow mating to the MDA and an S-IVB tank dome section. In addition, mock-ups of the external components and experiments will be attached during the launch configuration and solar array deployment tests.
4. AM Prototype Structure #1	This prototype structural article has a full Flight 2 structural configuration, capable of structural pressure integrity testing and static and dynamic testing to qualification levels. All internal and external components and experiments will be mass simulated.
5. AM Flight	This article has a Flight 2 configuration.
6. MDA Prototype Structure #2	This prototype structural article has a full Flight 2 structural configuration, capable of structural pressure integrity testing and static and dynamic testing to qualification levels. All internal and external components will be mass simulated. This structural article will have the proper interface to mate with the AM and all docking ports will be in the launch configuration (all ports sealed).

Test Article	Description
7. MDA Prototype Structure #1	This prototype structure article has a full Flight 2 structural configuration, capable of structural pressure integrity testing and dynamic testing to qualification levels. This structural article will have provisions to mate with the AM and will provide the proper mass simulation at the AM/MDA interfaces to allow dynamic testing of the AM in the launch configuration.
8. MDA Flight	This article has a Flight 2 configuration.
9. SLA Prototype	This existing SLA will be modified to a Flight 2 configuration, with the solar deployment system (mechanical and electrical) installed. Solar array mechanical simulators will be provided to check storage and deployment clearances and operation.
10. SLA Flight	This article has a Flight 2 configuration.
11. IU Flight	This article has a Flight 2 configuration.
12. S-IVB Flight	This article will be modified to the Flight 2 launch configuration.
13. S-IVB Mockups Prototype Segments	The S-IVB Mockup will have a full size internal workshop configuration with all component and experiment mockups installed in the orbit configuration. All prototype segments will be flight configured.

A test hardware summary of the Flight 1 and 2 test program is shown in figure 2. This hardware summary identifies all the Flight 1 and 2 carriers, the carrier contractors and the NASA centers responsible for the carriers. In addition, all carrier prototypes are identified, along with the required interface simulators to support the carrier test program.

2.2 Simulator Requirement Summary - Figure 3 presents a summary of the simulator requirements in tabular form. As an example of the use of the figure, consider the first two lines which identifies the simulator requirements for the CSM tests at NAA. Line two shows the MDA simulator requiring data, communications and D&C simulation. The X in the "MDA through connection simulation" column indicates that the MDA simulation in each of these systems is basically a through connection with line drops and attenuation, etc., consistent with the flight MDA. The actual functional components are in the AM simulator, consequently the AM, MDA and CSM simulators must be used together as shown in the sketch below.



Center Responsibility	Location	Flight Articles	Prototypes	Simulators **	
				SM#	Title
MSC	North American	CSM SLA	CSM (A) SLA (A)	1 2	AM MDA
	McDonnell	AM	AM (D) *MDA Structural #1 (A) *AM Structural #1 (A) *AM Structural #2 (A)	3 4 5 6 7	MDA CSM S-IVB Fwd. Mockup Experiment Sim. IU Pass. Mod.
MSFC	MSFC	MDA Nose Cone	MDA (D) *MDA Structural #1 (A) MDA Structural #2 (A) *AM Structural #2 (A) SLA (A) S-IVB (O) IU Structural (A)	8 9 10 11 12 13 14	AM CSM LM A/S Experiments Docking Collar AM Radiator AM & IU Comp. Mockups
	IBM	IU	IU (D)	15 16 17	S-IVB Pass. Mod. (Delete) AM
	Douglas	S-IVB	---	18 19 20	IU AM Exp. Sim.
KSC	KSC	CSM 1 SLA 1 SLA 2 AM MDA S-IVB 2 IU Nose Cone 2	---	21 22 23	LM/ATM IU/S-IVB CSM-3 Sim.

Legend:

- * Prototypes shipped between contractors
- ** Simulators are described in Appendix A by simulator item no.
- A Assumed
- B NASA Directive
- C Known Trainer
- D Flight Article
- O Available, but no planned usage

Figure 2. Test Hardware Matrix

The following notes are referenced on figure 3.

Note 1 - Data, communications and D&C interfaces through the MDA simulator. Power and reactant resupply (fluid and gas) interfaces directly with the SM. S-IVB loads on the AM carry in cable is simulated.

Note 2 - MDA structural model (prototype) will satisfy physical checks but has no functional components. Simulator required for functional checks. AM structural model shipped to MSC after MAC tests.

Note 3 - Data, communication and D&C interfaces through the MDA simulator. Power and reactant resupply interfaces directly with AM.

Note 4 - S-IVB forward mockup required for AM boot to S-IVB dome fit and leak checks.

Note 5 - Only the AAP modification portion of the IU is required (mainly the passivation mod and program changes).

Note 6 - Passivation mod portion of S-IVB only.

Note 7 - Structural checks of fit and clearance between AM and MDA will be accomplished with AM structural model. Simulator will not require physical properties.

Note 8 - LM A/S simulator must simulate ATM solar power as well as LM A/S to MDA connections.

Note 9 - Experiment physical property simulators required for every experiment for which developer is not providing a prototype.

Note 10 - Simulator must have both male and female docking provision to check all 5 ports. Capable of pressurizing simulator for leak check of ports and hatches.

Note 11 - AM radiator master gauge plate required if AM structural model does not have radiator section. Simulator must have precision dimensions, hole pattern and pressure seal.

Note 12 - IU shell and AM structural models do not have components. Mockups of AM & IU components required in areas of marginal clearance to facilitate launch configuration fit and clearance checks.

Note 13 - S-IVB and IU simulation required for cluster compatibility checks in MSOB (IU and S-IVB in VAB or AF hangar). Should provide simulation of OWS load variations during mission simulation (equipment and experiment activation).

Note 14 - Experiment simulators will be required for those experiments for which the developer does not provide a prototype.

Note 15 - CSM simulator will simulate only difference between CSM 1 and CSM 3.

Figure 3 Simulator Requirements Summary Sheet 1

HARDWARE AVAILABILITY				SIMULATION REQUIREMENTS			FUNCTIONAL SIMULATION												PHYSICAL SIMULATION								
CENTER RESPONSIBILITY	LOCATION	FLIGHT ARTICLES	PROTOTYPES	SIM. ITEM NO.	SIMULATION OF	REQUIRED FOR TEST OF	POWER	DATA	COMMUNICATIONS	ECS/LS ELECT.	THERMAL CONTROL	PROPULSION	G&N	D&C	FLUIDS/GAS	THROUGH CONN.			DOCKING PROVISION	ATTACH POINTS	SIZE SHAPE	WEIGHT, CG	RF REFLECTIVITY	COMP. MOCK UP	CONN. MATE CAPABILITY	PRESSURE	NOTES
MSC	NAA	CSM SLA	CSM (A)	1	AM	CSM modification design verification	X	X	X					X	X										X		1
				2	MDA			X	X					X		X			X						X		
	MAC	AM	MDA Structural (A) AM Flight (D)	3	MDA	AM design verification & qualification Flight AM acceptance	X	X	X	X	X			X	X	X									X		2
				4	CSM		X	X	X					X	X										X		3
				5	S-IVB Forward Mock up		X													X	X				X		4
				6	Experiments		X	X	X		X			X	X										X		14
				7	IU Passivation Modification		X							X											X		
MSFC	MSFC	MDA	Flight MDA (D) MDA Structural Unit (A) AM Structural Unit (A) IU Shell SLA	8	AM	MDA design verification and acceptance test	X	X	X	X	X			X	X										X		7
				9	CSM			X	X					X											X		
				10	LM A/S		X																		X		8
				11	Experiments															X	X	X			X		9
				12	Docking Collar & Pressure Sim.														X							X	10
				13	AM Radiator Master Gauge Sim.															X	X					X	11
				14	AM & IU Component Mockups															X	X			X			12

Figure 3. Simulator Requirements Summary

Figure 3 Simulator Requirements Summary Sheet 2

HARDWARE AVAILABILITY				SIMULATION REQUIREMENTS			FUNCTIONAL SIMULATION												PHYSICAL SIMULATION								
CENTER RESPONSIBILITY	LOCATION	FLIGHT ARTICLES	PROTOTYPES	SIM. ITEM NO.	SIMULATION OF	REQUIRED FOR TEST OF	POWER	DATA	COMMUNICATIONS	ECS/LS ELECT.	THERMAL CONTROL	PROPULSION	G&N	D&C	FLUIDS/GAS	THROUGH CONN.			DOCKING PROVISION	ATTACH POINTS	SIZE SHAPE	WEIGHT, CG	RF REFLECTIVITY	COMP. MOCK UP	CONN. MATE CAPABILITY	PRESSURE	NOTES
MSFC (Cont)	IBM	IU	Flight IU (D)	15	S-IVB OWS Passivation Mod.	IU design verification and IU acceptance	X		X																X		6
				16	(Deleted)																						
				17	AM Display and Control Sim.									X											X		
	Douglas	S-IVB OWS	Flight S-IVB (D)	18	IU	S-IVB OWS mod. design verification, acceptance and static firing	X		X																X		5
				19	AM		X	X	X	X				X	X										X		
				20	Experiment Sim.															X	X				X		
KSC	KSC	CSM AM MDA SLA S-IVB IU Nose Cone	None	21	LM/ATM	Prelaunch checkout Flights 1 and 2	X																		X		
				22	S-IVB/IU Interface Simulator		X	X	X	X		X		X	X										X		13
				23	CSM 3 Sim.		X	X	X					X												X	15

Figure 3. Simulator Requirements Summary

2.3 Evaluation - Using the prototypes, flight hardware and simulators described in the previous section, and based on the test activities shown in figure 1, valid qualification, design verification and flight hardware acceptance testing can be achieved on individual carriers.

Since individual carrier varification is not the primary concern of this study, an evaluation against detailed requirements has not been performed on the ability to verify individual carrier design.

The ability to verify inter-carrier and cluster compatibility has been evaluated against a set of specific requirements developed to evaluate various cluster configurations in report ED-2002-69. The results of this evaluation is shown on figure 10.

The evaluation of the effectiveness of the test program to satisfy the objective of proving design compatibility is summarized below. Figures 4-9, pages 30-35, illustrate the various test configurations that can be achieved in each area with the hardware and simulators previously identified.

The complexity of the module interfaces upon which the analysis is based is illustrated in the data contained in Appendix B.

2.3.1 General Evaluation - In general, the test program described would provide some level of confidence in probability of mission success, however, in many areas the adequacy is marginal and in a few instances, design compatibility cannot be verified to any extent.

The majority of the compatibility verification is performed at KSC with the inherent risk that detection of a design incompatibility at that point would have severe impact on both the flight schedule of that flight and on the total AAP program. The inability to perform potentially detrimental testing on the flight hardware at KSC will cause confidence in the validity of design safety margins derived by analysis to be questionable.

Several weaknesses exist in the Flight 2 test program which will create significant risks, however, the majority of the difficulty appears to be in the area of verifying the Flight 1/2 cluster compatibility.

It should also be noted that this evaluation is based on Flights 1 and 2 only and presents a somewhat fictitious picture since the main risk area is in proving the total cluster (AAP 1/2/3/4) compatibility.

a. The design compatibility verification between the AM and OWS is inadequate. The program does not provide for mating the AM with the S-IVB at any point prior to KSC. The AM boot to OWS dome fit, clearance and sealing method can be verified at MAC using the S-IVB simulator (partial dome and forward skirt mock-up). Douglas checks of the S-IVB using an AM simulator is inadequate for verifying compatibility. The extent of testing that can be performed on the AM/S-IVB combination at KSC is limited since mating will take place at the launch pad. One of the main risks would appear to be in inability to prove the adequacy of the AM cryogenic storage capacity which will be based on calculated cluster configuration leakage. The program does not afford an opportunity to verify the validity of the total leakage rate calculations. Testing cannot be accomplished at KSC since the test would require a complete passivation sequence on the LH_2 tank including internal sealing of the tank penetration points.

While the boot to dome fit check may be performed at MAC, they will not have an IU and SLA to verify access to and ability for attaching and leak checking the connection once it is stacked on the launch pad. The inability to perform an adequate pre-flight leak check would present a significant risk.

The complete activation and passivation sequence cannot be performed at any one location on a single combined test specimen. Each carrier - IU, AM, S-IVB - can be checked individually and some portions of the activation/passivation sequence can be verified at KSC on the flight AM/IU/S-IVB combination at the launch pad, however, the approach of performing segmented tests and combining the results by analysis to achieve system level confidence has proven to be inadequate in the past and it is felt that a significant doubt will exist at lift off in the ability to perform the passivation and activation of the OWS.

b. The individual test programs for the AM and the MDA should be adequate, however, the reliability of the flight articles will be subject to doubt due to the requirement to perform design verification testing on the flight articles. A comprehensive design verification program will require parametric testing and potentially detrimental tests such as off limits and over stress tests. Although refurbishment and re-acceptance prior to flight (replace components suspected of having been exposed to degrading conditions) could be considered, the difficulty is in determining, by analysis, which components may be on the failure threshold. A miscalculation could mean that a component will be on the failure threshold at lift off.

An important disadvantage of the approach, although only partially related to the Flight 2 test program, is the fact that there will be no flight configured AM and MDA against which to verify CSM 3 and LM AS/ATM compatibility since the only fully configured AM and MDA will be on-orbit before Flight 3 and 4 test programs start.

Another factor which must be considered is in the area of schedule constraints imposed by the use of single articles to accomplish design verification, acceptance, integration, and prelaunch checkout testing. As shown on the time based flow, figure 1, the series test program is extremely tight and leaves little room for contingency. Use of a flight configured prototype would permit concurrent testing and would provide a means for continuing the test program into the four month period where the flight hardware is at KSC to further establish confidence in the hardware design.

c. The main area of weakness in the test program is the inability to verify cluster compatibility and to establish an adequate level of confidence in cluster system design.

Probably the single most significant risk in this region is in the broad area of EMC verification with severe difficulty in verification that no cluster RFI problems exists. No single test location other than KSC has the hardware necessary to accomplish any verification of cluster EMC. All other locations require the extensive use of simulation in their test program and simulators cannot provide valid EMC test results.

The test activities at the MSOB can provide some valid verification of pure electro-magnetics but cannot be any verification of cluster RF compatibility due to the test configuration. The CSM will be inside the altitude chamber of the MSOB. The AM/MDA will be adjacent to the chamber and mated to the CSM in the chamber via long marriage cables. The IU and S-IVB will be functionally simulated.

Verification of the effects of the varying RF fields, intensities and fundamental and harmonic frequency mixing created by antenna radiation and RF reflections cannot be verified. Establishing confidence through engineering analysis would appear to be an insurmountable task.

Related to the inability to verify EMC is the risk that the test program will not provide a means for detecting cluster communication problems associated with antenna masking and reflected RF interference falling within receiver bandpasses.

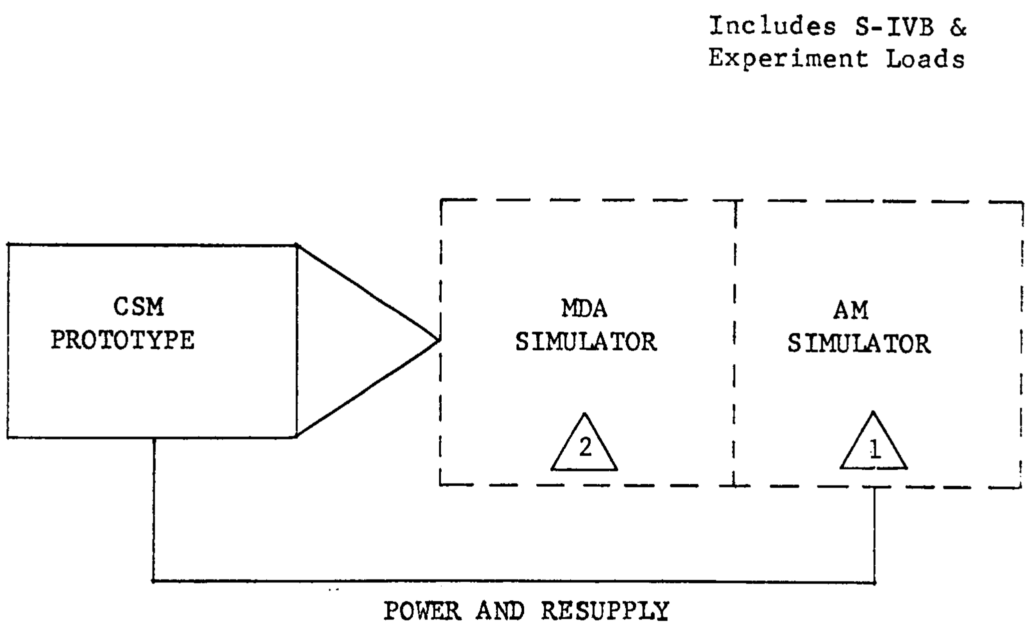
Analysis may establish some level of confidence that antenna masking will not occur. The problem of interference with the onboard receivers, however, may present a complex condition which defies satisfaction by analysis. While this could present some problems on the flight 1/2 cluster, the real severe problem will be created by the AAP 1/2/3/4 cluster.

d. Several other areas of test activities appear to be weak, although the significance of the risks involved is less severe and some confidence can be established through analysis of individual carrier tests and the probable effects on the cluster systems.

Cluster man-machine compatibility and mission time line verification cannot be completely satisfied by the test program, however, most of these activities lend themselves to segment testing and analysis.

Cluster mechanical clearances problems (e.g., solar panel deployment, etc.) cannot be adequately verified and may impose a requirement to provide larger specification clearance envelopes to avoid marginal clearances.

e. Cluster system contingency planning and FMECA verification cannot be adequately demonstrated. While this may present a risk factor, a more significant problem area will exist in the inability to verify these items in the AAP 1/2/3/4 cluster.



CSM CLUSTER DESIGN VERIFICATION

Figure 4. NAA Test Configurations

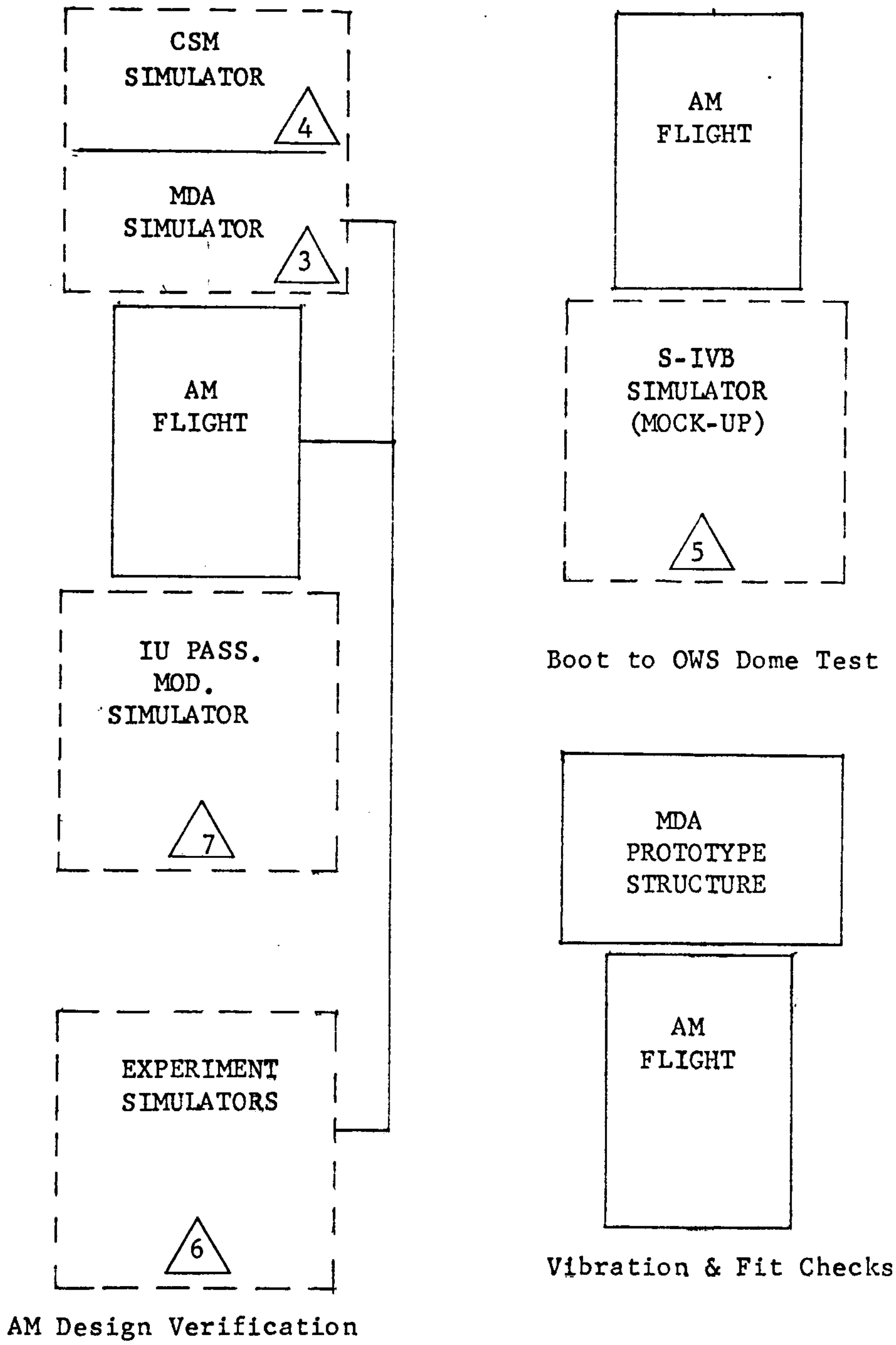
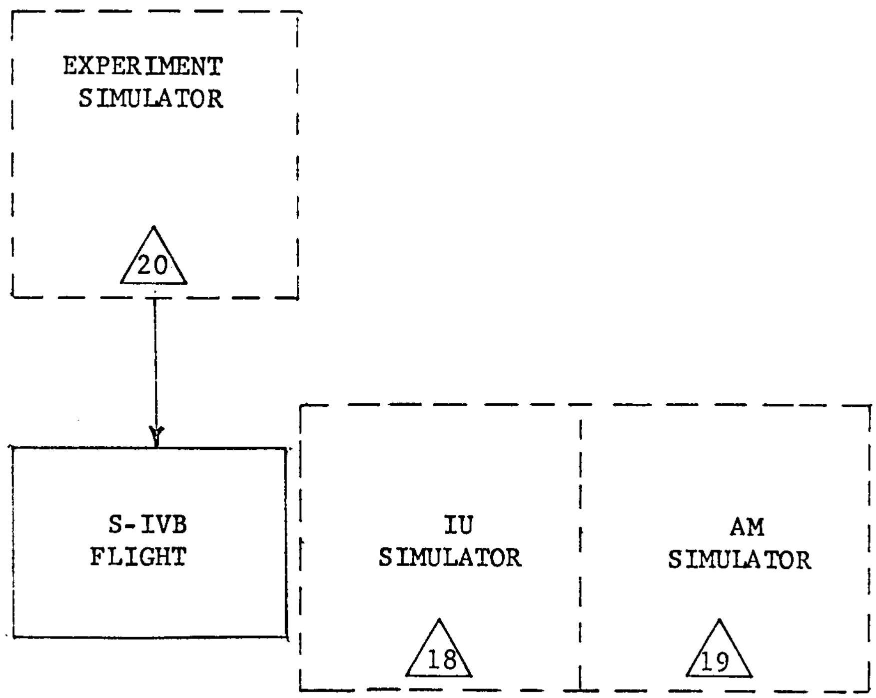
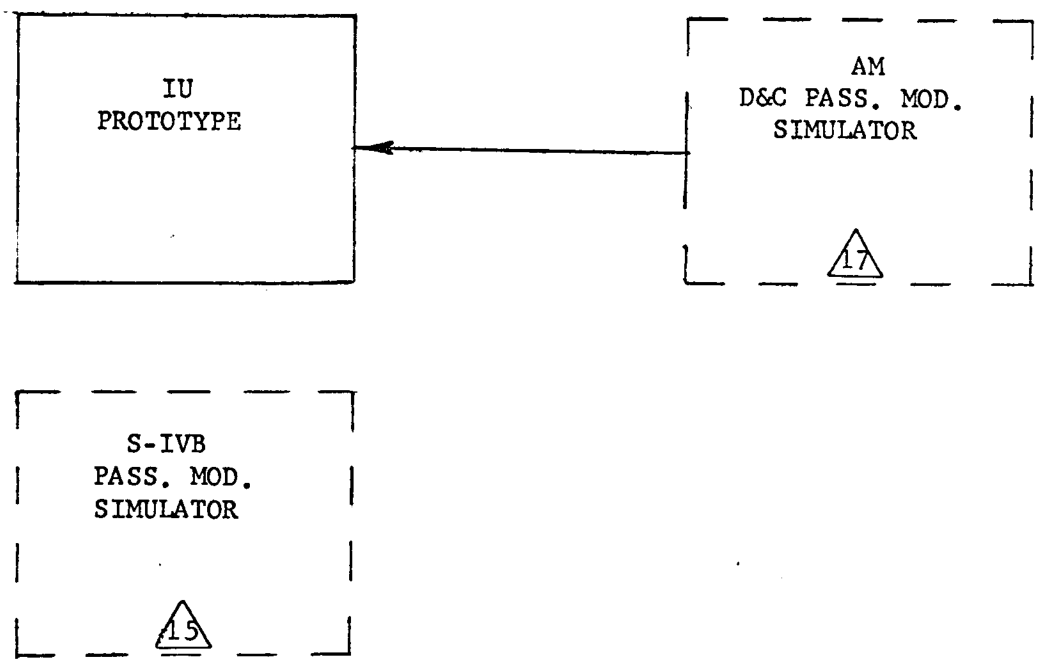


Figure 5. MAC Test Configurations



S-IVB Mod Design Verification and Experiment
Fit & Clearance Check

Figure 6. Douglas Test Configurations



IU Design Verification

Figure 7. IBM Test Configurations

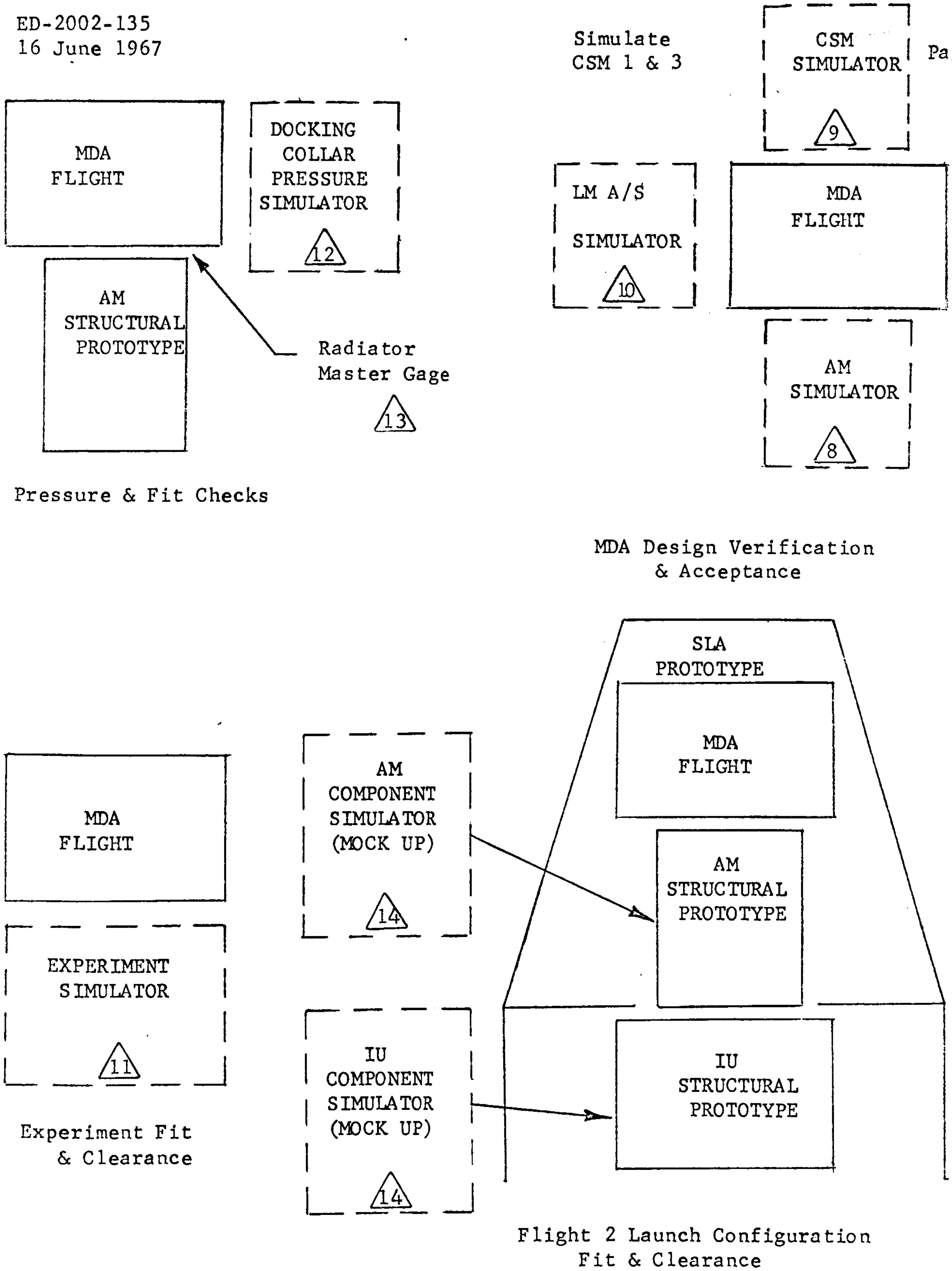
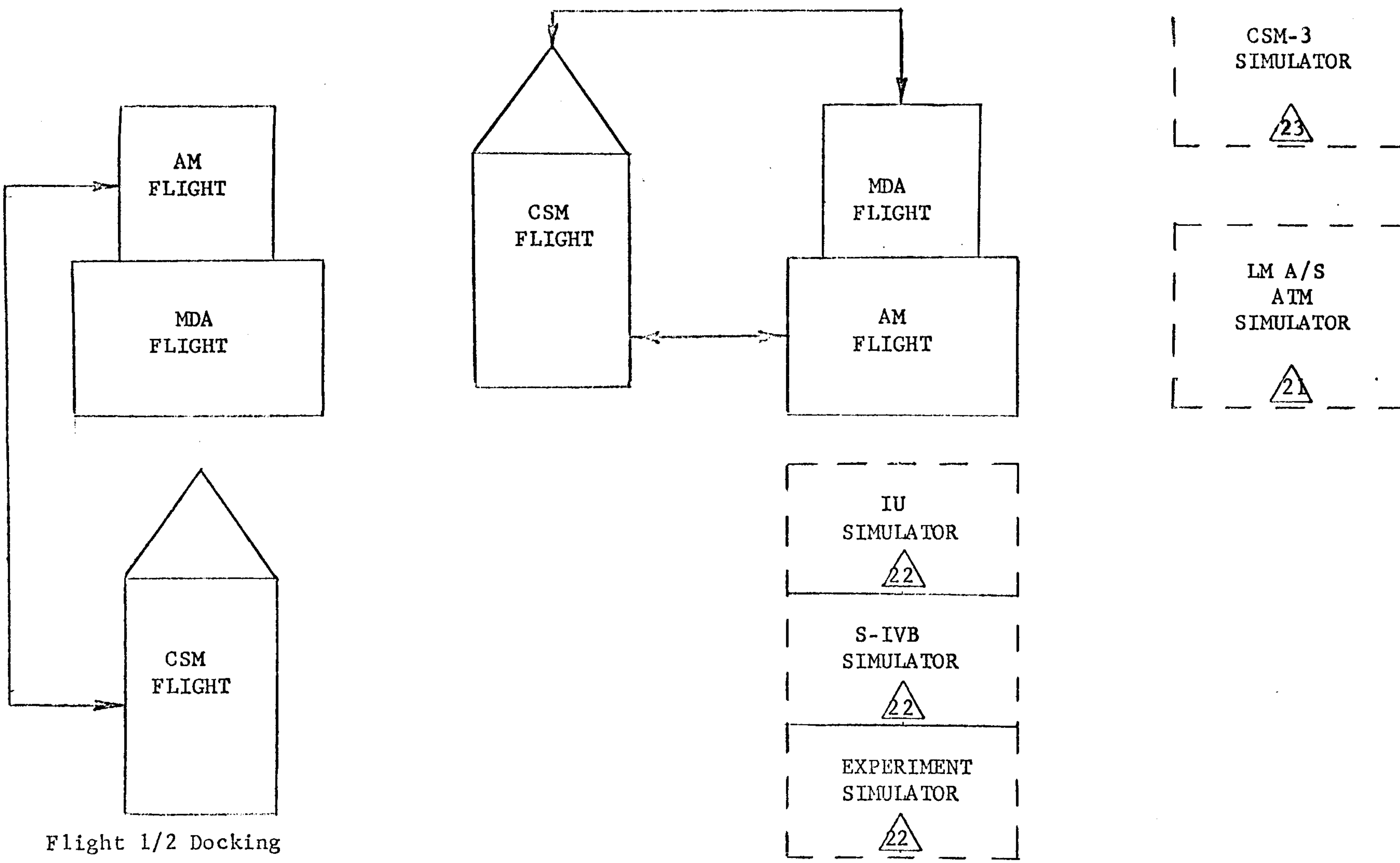


Figure 8. MSFC Test Configurations



Flight 1/2 Docking

Flight 1/2 Functional Compatibility Checks

Figure 9. KSC Test Configurations

2.3.2 Evaluation Against Specific Requirements - The following sheets provide an evaluation of the test program against more specific test requirements. The first column identifies a specific test requirement. The next eight columns indicate the location where testing of this requirement may occur, but does not necessarily indicate that any one location or combination of locations satisfy the requirement completely.

The next column assigns an evaluation figure to the ability of the test program to satisfy that requirement. Ratings are in descending order from 10 to 1 with 10 being high. The meaning of the ratings can be grouped into three categories as follows:

1-4 indicates that the test requirement cannot be satisfied by this program, and that a relatively high risk factor is involved.

5-7 indicates that the test program is marginal in this area. The significance of this rating would probably be influenced by the extent and quality of supplemental engineering analysis but confidence in design compatibility would probably be lower than desirable.

8-10 indicates that the test program appears to be adequate in this area and should provide sufficient test verification.

The final column provides a brief rationale for the evaluation rating assigned in the preceding column.

TEST REQUIREMENT	TEST AREA: NAA	LOCK.	MAC	MSC	DOUG.	IBM	MSFC	KSC	EVALUATION RATING	EVALUATION RATING JUSTIFICATION
SM Power System										
1. Compatibility with AM/MDA Distributor feeding OWS (AAP 1/2 cluster)	X							X	7	Test activities at NAA using interface simulation of MDA & AM will provide some degree of verification of design but the majority of this requirement will be satisfied at KSC when the flight CSM, AM & MDA are functionally mated. Some derating occurred due to inability to perform power system parametric and off limits testing on flight hardware at KSC and the inability to obtain valid results at NAA with three of the four carriers simulated. Risk of detecting design incompatibilities at KSC.
2. Switching and isolation compatibility with the SLA solar power system (or S-IVB solar power)								X	9	The only place that a flight configured SLA, AM and CSM are together is at KSC. Main risk again is late detection of incompatibility, however, lower level (assembly & subsystem) testing should reduce this risk.

Figure 10. Evaluation Against Detailed Requirements (AAP 1/2)

TEST REQUIREMENT	TEST AREA								EVALUATION RATING	EVALUATION RATING JUSTIFICATION
	NAA	LOCK.	MAC	MSC	DOUG.	IBM	MSFC	KSC		
IU Power System										
1. Compatibility with S-IVB passivation circuits					X			X	8	IBM testing using an S-IVB passivation mod simulator coupled with the KSC launch pad checks of the automation portion of the modification should provide adequate verification of compatibility.
2. Switching compatibility with SLA solar power (or S-IVB solar power)						X		X	6	Check at IBM with SLA sim. Checks at KSC in VAB using sim. Actual SLA/IU checks with flight configured hardware never accomplished.
3. Mission sequence compatibility						X		X	7	Partial check at IBM - tape program, sequence using S-IVB, SLA sim. with some additional checkout at KSC, but limited in parametric and off limit tests.
Fluids, CSM										
1. Reactant (fuel cell) resupply capability with AM	X							X	7	Checks at NAA with AM simulator using cryogenics. Checks at KSC-MSOB between AM and CSM uses gas only. Never check flight configured AM & CSM using cryogenics.

Figure 10. Evaluation Against Detailed Requirements (AAP 1/2) (continued)

TEST REQUIREMENT	TEST AREA NAA	LOCK.	MAC	MSC	DOUG.	IBM	MSFC	KSC	EVALUATION RATING	EVALUATION RATING JUSTIFICATION
Fluids, AM/MDA										
1. Compatibility with SM fuel cell system (reactant re-supply)			X					X	7	Checks at MAC using CSM simulator. Check at KSC uses gas only. Cryogenics never used on flight configured CSM-AM.
2. Oxygen, nitrogen LS compatibility with OWS			X						2	AM/S-IVB never mated until KSC. No activation exercise performed there. MAC checks run with S-IVB mockup. AM design capacity cannot be verified as adequate. Cluster leakage calculations cannot be verified.
3. Mission sequence compatibility			X						6	Electrical sequencing and fluid flow can be verified at MAC to some extent. Design compatibility between AM/OWS cannot be verified in terms of capacity, leakage, regulation, etc.
Fluids, OWS										
1. Compatibility with AM life support source					X				2	Douglas checks with an AM simulator are inadequate for design verification. AM/OWS checks at KSC using cryogenics are not planned (electrical checks will be performed).

Figure 10. Evaluation Against Detailed Requirements (AAP 1/2) (continued)

TEST REQUIREMENT	TEST AREA NAA	LOCK.	MAC	MSC	DOUG.	IBM	MSFC	KSC	EVALUATION RATING	EVALUATION RATING JUSTIFICATION
Communication, CSM										
1. Voice communications compatibility with the AM	X							X	10	Inadequate capability at NAA (AM sim. only) will be supplemented by flight AM to CSM communication check at MSOB.
2. Voice communications compatibility with OWS	X							X	7	No actual CSM to OWS (inside LH_2 tank) check is possible at any location. Segment tests (e.g., CSM to AM checks at KSC, OWS check) at Douglas plus engineering analysis should provide some level of confidence.
3. Voice communications with EVA, all potential interference sources operating	X								2	Very limited capability at NAA (no interference sources), no capability at KSC (CSM inside altitude chamber). No area has capability to verify since no area has a full cluster.
4. Data communications compatibility with OWS (TV monitor) via AM/MDA	X							X	8	CSM monitor/receiver checks at NAA, TV camera checks at MAC (if carry in) or at Douglas (if pre installed) coupled with analysis and cable checks through MDA and AM should provide some confidence. System check is possible at KSC if camera is stored in AM or MDA and OWS cabling is carry in.

Figure 10. Evaluation Against Detailed Requirements (AAP 1/2) (continued)

TEST REQUIREMENT	TEST AREA: NAA	LOCK.	MAC	MSC	DOUG.	IBM	MSFC	KSC	EVALUATION RATING	EVALUATION RATING JUSTIFICATION
Communications, AM/MDA										
1. Through connection data compatibility, OWS to CM			X				X	X	7	Limited capability at MAC and MSFC through use of simulators. Good check is possible at MSOB using flight hardware, however, restricted in parametrics, FMECA validation and lack of one terminal point (OWS).
2. Through connection voice compatibility, CM to LM and CM to OWS			X				X	X	6	Checks at MAC and MSFC limited by use of simulator. Checkout at KSC limited since two of the three communication stations are not there (LM and inside OWS). OWS portion can be adequately checked if communication cable is a carry in (coiled on AM). LM to CM communications through AM/MDA will not be completely verified until on-orbit.
3. Voice compatibility, CM to AM via MDA			X				X	X	10	MAC and MSFC checks limited by simulation. KSC checks should complete since AM/MDA is functionally mated to CSM in MSOB. Risk is late discovery of incompatibility.

Figure 10. Evaluation Against Detailed Requirements (AAP 1/2) (continued)

TEST REQUIREMENT	NAA	LOCK.	MAC	MSC	DOUG.	IBM	MSFC	KSC	EVALUATION RATING	EVALUATION RATING JUSTIFICATION
Communications, OWS										
1. Voice compatibility with AM			X		X			X	8 or 6*	If the OWS cable is a carry in stowed on AM, both MAC and KSC can perform adequate verification although some aspects of performance (interference, operation inside LH_2 tank) cannot be checked. If cable is pre-installed in tank, ability to establish confidence in compatibility through individual Douglas and MAC checks is questionable.
2. Voice compatibility with CM via AM/MDA			X		X		X	X	8 or 6*	Inadequate check at MAC and MSFC due to extensive simulation. Adequate check at KSC on flight CSM, AM, MDA if cable is AM-stored carry in. Verification questionable if pre-installed in LH_2 tank.
3. Data compatibility with CM via AM/MDA			X		X		X	X	7 or 5*	Same as 2 above, however, system is more complex and grounding, shielding and externally generated interference checks are more critical. Adequacy of design verification is marginal at best.

Figure 10. Evaluation Against Detailed Requirements (AAP 1/2) (continued)

TEST REQUIREMENT	TEST AREA								EVALUATION RATING	EVALUATION RATING JUSTIFICATION
	NAA	LOCK.	MAC	MSC	DOUG.	IBM	MSFC	KSC		
Communications (OWS) (continued)										
4. Voice compatibility with EVA, all interference generators operating			X		X			X	4	While some confidence can be achieved through checks at MAC and Douglas, the extensive use of simulators tends to invalidate compatibility data. KSC checks will use most of the flight hardware but orientation (CSM in chamber, AM/MDA outside chamber, no S-IVB at MSOB) does not provide a basis for verification of operation in the cluster RF field.
5. Data communications compatibility with AM distribution network			X		X			X	7 or 5*	Same as Item 1 above. Added complexity of system makes checkout of both carry in and pre-wired concept marginal.
6. Mission sequence compatibility			X		X			X	6	Extensive use of simulators at MAC and Douglas invalidates compatibility verification. KSC checks on flight hardware are limited in areas of parametric testing, contingency and FMECA verification during mission sequence.

Figure 10. Evaluation Against Detailed Requirements (AAP 1/2) (continued)

TEST REQUIREMENT	TEST AREA								EVALUATION RATING	EVALUATION RATING JUSTIFICATION
	NAA	LOCK.	MAC	MSC	DOUG.	IBM	MSFC	KSC		
Display and Control, CSM										
1. Compatibility with MDA sensors	X							X	10	Fairly valid checks at NAA since only the end instruments in MDA require simulation and complete verification is possible at KSC.
2. Compatibility with AM sensors via MDA	X							X	10	Same as above.
3. Compatibility with OWS sensors via AM/MDA	X							X	8 or 7*	Valid check possible at KSC if carry in cable, questionable if pre-wired. NAA tests cannot prove compatibility due to extensive simulation.
Display and Control AM/MDA										
1. MDA compatibility with AM			X				X	X	8	Limited capability at MAC & MSFC using simulators. Flight AM to MDA tests at KSC should be adequate but limited in amount of design verification tests possible (off limits, etc.).
2. AM compatibility with IU (passivation mod display & contol panel)			X					X	7	Limited check at MAC with IU simulation. Launch pad check at launch pad (KSC) is possible, but late in flow to perform a first time functional check of flight configured hardware.

Figure 10. Evaluation Against Detailed Requirements (AAP 1/2) (continued)

TEST REQUIREMENT	NAA	LOCK.	MAC	MSC	DOUG.	IBM	MSFC	KSC	EVALUATION RATING	EVALUATION RATING JUSTIFICATION
Display and Control AM/MDA (continued)										
3. AM compatibility with OWS			X					X	10 or 6*	MAC can perform complete test if carry in cable and panels. If pre-installed, limited check at KSC (launch pad) is possible, but manual controls cannot be manipulated.
Display and Control, OWS										
1. Compatibility with AM					X			X	8 or 5*	Some verification possible at Douglas with AM simulators if pre-installed. MAC test will be adequate if carry in cable in the area of system D&C but the experiment panels are stored in MDA. KSC checks are capable of complete checkout at MSOB if carry in cable. Partial checkout at launch pad if pre-installed in LH_2 tank (no manual control checks).
2. Passivation mod compatibility with the IU (program and hardware)					X			X	6	Douglas check of S-IVB using IU simulator. Additional individual IU & S-IVB checks at MSOB. Mated IU and S-IVB system test at launch pad (limited capability for design verification).

Figure 10. Evaluation Against Detailed Requirements (AAP 1/2) (continued)

TEST REQUIREMENT	TEST AREA: NAA	LOCK.	MAC	MSC	DOUG.	IBM	MSFC	KSC	EVALUATION RATING	EVALUATION RATING JUSTIFICATION
Display and Control, IU										
1. Automatic control compatibility with S-IVB passivation mod						X		X	7	IBM checkout of program changes and IU design using S-IVB simulator will provide some verification. Individual IU & S-IVB check at MSOB. Mated IU & S-IVB checkout at launch pad. (limited design verification)
2. Manual control compatibility from AM to OWS via IU						X		X	8	Limited verification at IBM using AM D&C simulator. Verification at launch pad is possible but late.
3. Updata link control of passivation via IU						X		X	10	Complete checkout possible at IBM and KSC.
4. Passivation signal display to CM via AM and MDA	X							X	8	Very limited compatibility verification at NAA due to extensive simulation. Checkout at launch pad possible but late.
Overall Systems Compatibility C Checks Functional										
1. Flight 1/2 cluster configuration mission sequence compatibility								X	7	Can accomplish good verification of cluster functional compatibility at KSC with IU, S-IVB simulation. Parametrics, off limits, etc. at cluster level not possible.

Figure 10. Evaluation Against Detailed Requirements (AAP 1/2) (continued)

TEST REQUIREMENT	TEST AREA								EVALUATION RATING	EVALUATION RATING JUSTIFICATION
	NAA	LOCK.	MAC	MSC	DOUG.	IBM	MSFC	KSC		
EMC Compatibility										
1. Flight 1/2 cluster configuration EMC compatibility								X	4	The KSC cluster test should provide some capability for verification but does not provide any capability for RF compatibility checks due to orientation (CSM in chamber, AM/MDA adjacent to chamber, S-IVB & IU simulated). No other area can prove EMC.
Launch Configuration Compatibility										
1. Flight 1 fit and clearance checks								X	10	Complete verification at KSC on flight hardware.
2. Flight 1 launch configuration EMC checks								X	7	RF open loop tests at the launch pad. Test is not comprehensive but no RF problems anticipated during boost phase.
3. Flight 2 fit and clearance checks							X	X	10	Complete verification at MSFC on prototype and at KSC on flight hardware.
4. Flight 2 launch configuration EMC								X	7	RF open loop tests at the launch pad are minimal but potential boost phase RFI problems should be limited.

Figure 10. Evaluation Against Detailed Requirements (AAP 1/2) (continued)

TEST REQUIREMENT	TEST AREA								EVALUATION RATING	EVALUATION RATING JUSTIFICATION
	NAA	LOCK.	MAC	MSC	DOUG.	IBM	MSFC	KSC		
Experiment Compatibility										
1. Flight 1/2 cluster experiment/ system compatibility		X	X					X	5	Should be able to prove functional compatibility by analysis using results of MAC, Lockheed and KSC tests. Problems associated with compatibility when operated inside OWS (proximity, EMC, cross coupling) cannot be verified.
Man-Machine Compatibility										
1. Flight 1 compatibility								X	9	Should provide good confidence through manned tests at KSC. Derated on basis of problems associated with test orientation and performance in one G.
2. Flight 1/2 cluster compatibility					X			X	5	Ability to prove man-machine compatibility in one G and in test orientation is questionable. Some problem would exist if a full cluster test is employed. It is assumed that man-machine tests will be run as separate activities using bouyancy methods such as submersion in a pool.

Figure 10. Evaluation Against Detailed Requirements (AAP 1/2) (continued)

TEST REQUIREMENT	TEST AREA								EVALUATION RATING	EVALUATION RATING JUSTIFICATION
	NAA	LOCK.	MAC	MSC	DOUG.	IBM	MSFC	KSC		
Structural/Mechanical Compatibility										
1. CSM to MDA docking checks	X						X	X	10	Tests on MDA and CSM using master gages or docking collar and pressure simulators at MSFC and NAA respectively plus flight flight hardware docking test at KSC.
2. AM/MDA to SLA 2 fit and clearance			X				X	X	10	Checks at MSFC of flight MDA, structural prototype AM and prototype SLA. Flight hardware checks at KSC.
3. AM boot to OWS dome fit, alignment and pressure leak checks			X					X	7	Boot fit and alignment check at MAC using a partial S-IVB dome mockup. Flight AM to S-IVB dome fit, alignment and leak checks at KSC on launch pad. Adequate verification may be hindered by limited access after the AM & S-IVB are stacked at the pad. Risk of late detection of incompatibility.
4. Cluster configuration EVA, access, mechanical interference (deployment of solar panel, SLA petals, etc.)	X						X		5	Limited verification. NAA can demonstrate SLA & SLA solar panel deployment but does not have other cluster carriers for clearance checks. MSFC checks should be

Figure 10. Evaluation Against Detailed Requirements (AAP 1/2) (continued)

TEST REQUIREMENT	TEST AREA								EVALUATION RATING	EVALUATION RATING JUSTIFICATION
	NAA	LOCK.	MAC	MSC	DOUG.	IBM	MSFC	KSC		
Structural/Mechanical Compatibility (continued) 4. (continued)										more complete but again numerous carriers which could cause mechanical interference are missing.
Verification of Contingency Planning and Validation of FMECA										
1. Verify Flight 1/2 cluster failure mode effects analysis									2	No valid test can be performed in any area other than KSC. This type of test activity (simulated malfunctions) could be detrimental to hardware and should not be performed on flight carriers. Some confidence may be established by analysis of individual carrier tests (prototype).
2. Verification of cluster system automatic corrective action and design redundancy								X	4	Some verification can be accomplished at KSC especially on automatic corrective action. Limited redundancy checks since this involves disabling 1/2 of dual circuits or systems in many cases and should not be performed on flight hardware especially at KSC during prelaunch checkout.

Figure 10. Evaluation Against Detailed Requirements (AAP 1/2) (continued)

TEST REQUIREMENT	TEST AREA								EVALUATION RATING	EVALUATION RATING JUSTIFICATION
	NAA	LOCK.*	MAC	MSC	DOUG.*	IBM	MSFC	KSC		
Verification of Contingency Planning and Validation of FMECA (continued)										
3. Verification of alternate experiment grouping analysis - effect on cluster functional, EMC, man-machine	X		X				X		7	Individual verification of carrier/experiment compatibility can be accomplished at NAA, Lockheed and MSFC. Effects of alternate grouping on cluster systems when operating in on orbit location (inside LH_2 tank) cannot be verified but confidence may be established by analysis of individual carrier tests.
Ground-Orbit Compatibility Verification										
1. Flight 1/2 cluster compatibility with tracking stations and mission control								X	7	All CSM transmission systems can be verified as compatible, however, a cluster orientation is never achieved and the effects of varying RF fields, RF reflections and masking cannot be evaluated.

* First rating is for carry in cables - second rating for pre-wired cable

Figure 10. Evaluation Against Detailed Requirements (AAP 1/2) (continued)

3. FLIGHT 3/4 TEST PROGRAM

3.1 General Description - The test program described in this report is that portion of the total Flight 3 and 4 test program relating to the verification of intercarrier and cluster systems compatibility. This basic test program is shown in the time based test and checkout sequence shown in Figure 11. This test sequence shows the basic testing proposed for the individual qualification and flight carriers and the testing proposed between flight carriers to verify their intercarrier compatibility. The test program is based on the ground rule that all carriers would be integrated and tested at the carrier contractor's facility and that KSC will do the verification of intercarrier and cluster systems compatibility. This test program utilizes flight articles, which are available at KSC, to demonstrate intercarrier and cluster systems compatibility. However, the verification of Flight 2 and 4 orbit compatibility at KSC is limited by the test constraints imposed on the flight carriers (i.e., operating limits, number of cycles, schedules, etc.) and the inability to hard dock these carriers in a cluster configuration. This implies that only limited cluster systems compatibility testing can be accomplished with the proposed test program.

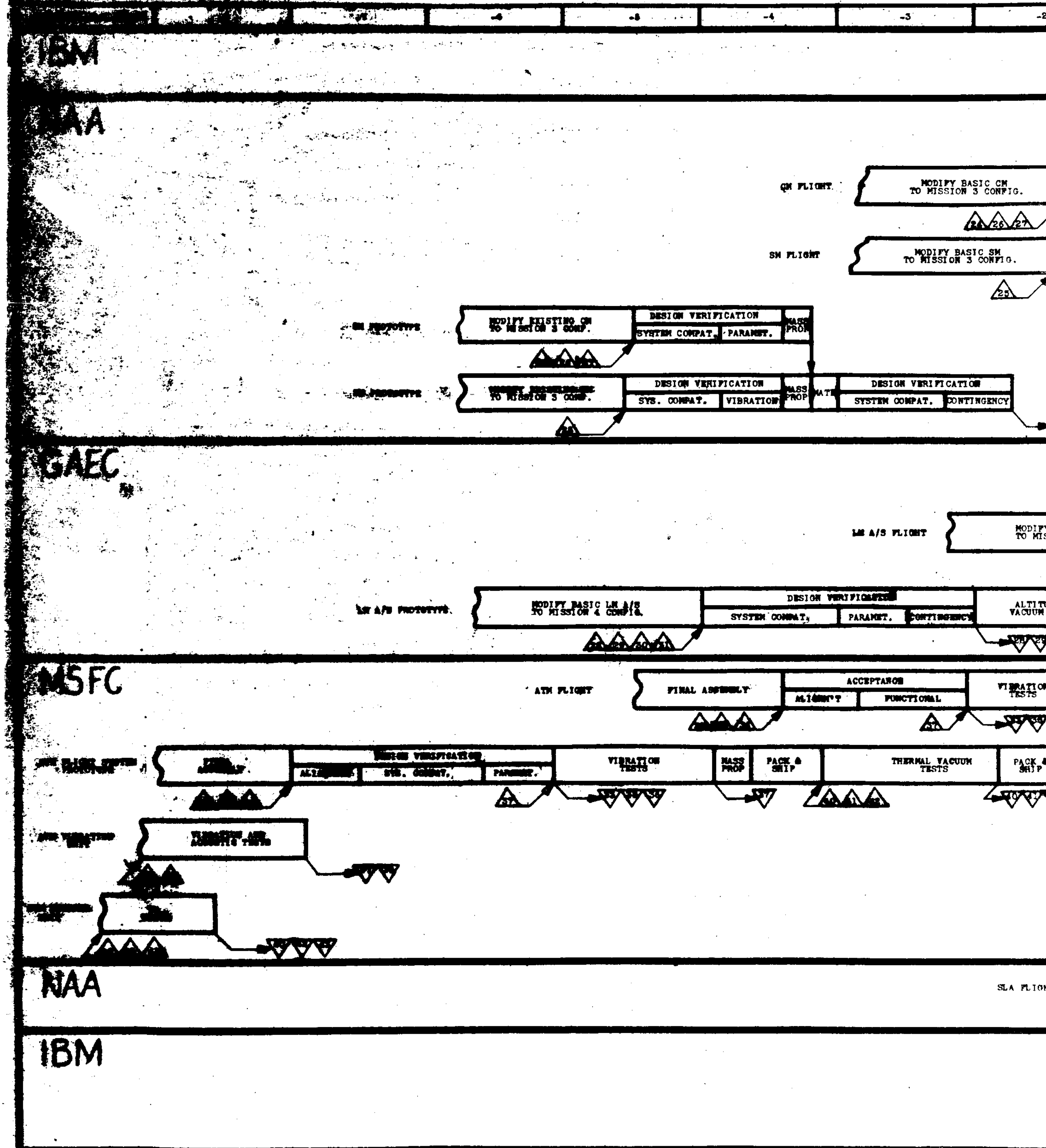
The cluster system interface verification with Flight 2 modules is not demonstrated in this program. The physical interface with the Flight 2 carriers is verified by the use of carrier simulators. These electrical and mechanical carrier simulators are utilized at KSC to verify correct physical and functional interfaces at the CSM 3 and MDA/AM interface and the LM and MDA interface. Flight carriers from Flights 1 and 2 and Flights 3 and 4 are never mated due to carrier availability and the 6 month difference in launch schedule.

The portion of the flight 3 and 4 test program that is not described in this report includes carrier development test programs and the subsystem, component, experiment and materials test programs. These programs, with the exception of the cluster system mockup, do not have a significant effect on the verification of the carrier interface. The cluster system mockup will be utilized to verify cluster system physical interfaces, clearances, access, etc. The proposed test program shown in the Flight 3 and 4 Time Based Test and Checkout Sequence has some significant changes over that proposed for the cluster test program.

The test time at KSC has been extended one month over that proposed for the cluster test program. The specific areas are:

FOLDOUT FRAME 1

AAP FLIGHT 3-4 TIME BASED TEST AND CHECKOUT SEQUENCE



NOTES:

1. CODE:

△ -SIMULATOR REQUIRED

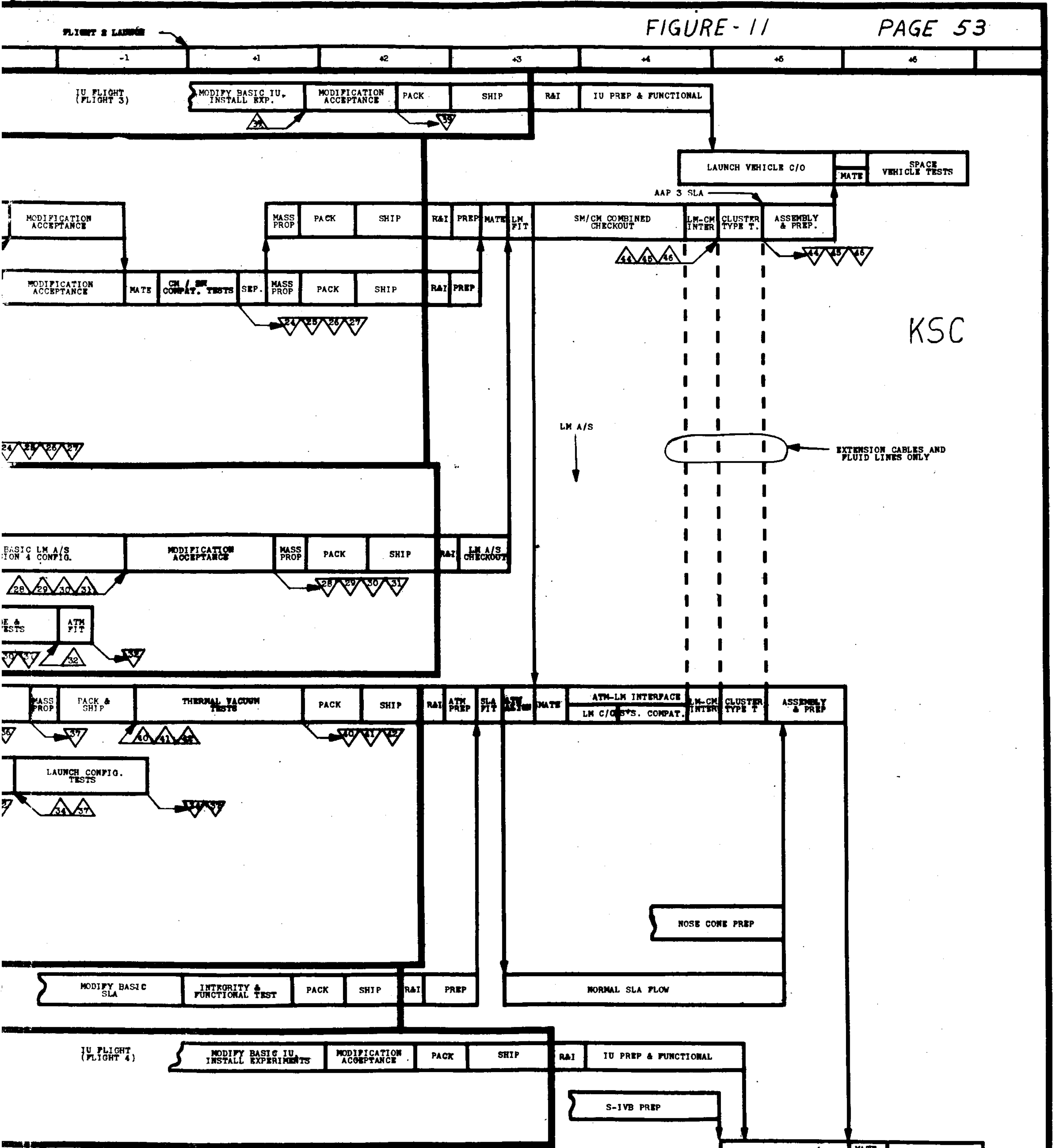
▽ -SIMULATOR USAGE COMPLETE

2. THE NUMBER IN THE TRIANGLE REFERS TO A SPECIFIC SIMULATOR ITEM NUMBER. EACH SIMULATOR IS DESCRIBED IN APPENDIX "A" BY ITEM NUMBER.

3. SIMULATOR IDENTIFICATION

24	LM A/S
25	AM
26	MDA
27	EXP SIMULATORS
28	ATM
29	CSM
30	MDA
31	AM
32	RACK PARTIAL MOCKUP
33	SOLAR POWER SIM.
34	S-IVB PARTIAL MOCKUP
35	LM A/S
36	EXP SIMULATOR
37	LM A/S PARTIAL MOCKUP
38	COMP & EXP MASS PROP.
39	CM D&C
40	LM THERMAL SIM.
41	LM A/S SIM
42	SOLAR PANELS
43	COMP & EXP THERMAL SIM.
44	
45	
45	

FIGURE - 11



4. ABBREVIATIONS

PARAMET	PARAMETRICS	INTER	INTERFACE
COMPAT	COMPATIBILITY	C/O	CHECKOUT
CONFIG	CONFIGURATION		
T	TESTS		
SYS	SYSTEM		
EXP	EXPERIMENTS		
PREP	PREPARATION		

AAP FLIGHT 3 & 4 TIME BASED TEST AND CHECKOUT SEQUENCE

JUNE 16, 1967

a. The cluster type tests involving the CSM, ATM and LM. This test sequence was extended one week to verify the cluster systems compatibility. This is the first time that flight configured hardware has been assembled in a partial cluster configuration.

b. The compatibility tests of the LM/ATM combination. This functional test was extended three weeks to verify the compatibility of the LM and ATM. This is the first time the flight configured LM and ATM have been mated.

The time based test and checkout sequences were derived from the ground rules in section 1.0 of this report and from a technical evaluation of the program requirements. The test programs for the IU, LM and ATM were based on information from MSFC, the CSM test program was based on a previous test program developed for AEP and the KSC test program was based on the Martin test program proposed during the Phase C Study (Report ED-2002-49).

The time based test and checkout sequence shows the carrier flow and the major carrier simulators that are required during each test phase of this flow.

The simulator requirements for each test are indicated by a number enclosed in a triangle. A triangle with an arrow pointing toward the carrier test flow indicates that the simulator is required during the test sequence(s) until another arrow leaves this test flow and points to a triangle with the same number. This indicates that the simulator usage is no longer required. The number in the triangle refers to a specific simulator item number. Each simulator is described in Appendix A by this item number.

The simulator requirement summary, Figure 13, Page 61, defines the requirement for each experiment simulator and identifies the test requirement that is satisfied by the test involving this simulator.

An arrow at the end of a test sequence indicates that the carrier is moved to be mated with other carriers either for test or assembly.

The basic carriers shown in the AAP Flights 3 and 4 Time Based Test and Checkout Sequence have the following configurations:

Test Article	Description
1. SM & CM Prototype	These prototypes are modified to have the full Flight 3 configuration.
2. SM & CM Flight	These articles have a Flight 3 configuration.
3. IU Flight (3)	This article has a Flight 3 configuration, including experiments
4. LM A/S Prototype	This prototype will be modified to have the full flight 4 configuration.
5. LM A/S Flight	This article has a flight 4 configuration.
6. ATM Thermal Unit	This unit has a full ATM structural configuration, capable of thermal vacuum testing, with the thermal properties of each ATM component or experiment simulated. This thermal unit will have the proper thermal coating and surfaces representative of the flight configured ATM, will have the LM attach points for attachment of the ATM to the LM thermal simulator during thermal vacuum testing, and will have the solar panel attach points to mount the solar panel simulators.
7. ATM Vibration Unit	This unit has a full ATM structural configuration, capable of static and dynamic testing to qualification levels. All internal and external subsystem components and experiments will be mass simulated. This unit will have the SLA attach points for attachment to the SLA simulator and the LM attach points for placement of the LM mass simulator on the ATM during vibration testing.

Test Article		Description
8.	ATM Flight System Prototype	This prototype will have a complete ATM configuration including all experiments.
9.	ATM Flight	This article has a flight 4 configuration.
10.	SLA Flight (4)	This article has a flight 4 configuration.
11.	IU Flight (4)	This article has a flight 4 configuration including experiments.

A test hardware summary of the flight 3 and 4 test program is shown in Figure 12. This hardware summary identifies all the Flight 3 and 4 carriers, the carrier contractors and the NASA centers responsible for the carriers. In addition, all carrier prototypes are identified, along with the required interface simulators to support the carrier test program.

Center Resp.	Location	Flight Articles	Prototypes	Simulators **	
				SM #	Title
MSC	NAA	CSM	CSM (C)	24	LM A/S
		SLA 3 & 4	SLA (A)	25	AM
				26	MDA
				27	Exp. Sim.
	Grum	LM A/S	LM A/S (A)	28	ATM
				29	CSM
				30	MDA
				31	AM
				32	Rack Partial Mockup
MSFC	MSFC	ATM	ATM Proto (B)	33	Solar Power Sim.
			ATM Vibration Unit (B)	34	S-IVB Partial
			IU Shell (B)	35	Mockup
			SLA (A)	36	LM A/S
			ATM Therm. Model (B)	37	Exp. Sim.
				38	LM A/S Partial Mockup
					Comp. & Exp. Mass Property
	IBM	IU 3	IU (D)	39	CM D&C
	Off-Site	*ATM	*ATM Proto (B)	40	LM Thermal Sim.
			*ATM Therm. Mod (B)	41	LM A/S Sim.
				42	Solar Panels
				43	Comp. & Exp. Thermal Sim.
KSC	KSC	CSM 3	None	44	MDA
		IU 3 & 4		45	AM
		S-IVB 3 & 4		46	S-IVB OWS Exp. & Sys.
		Nose Cone			
		ATM			
		LM A/S			
		SLA 3 & 4			

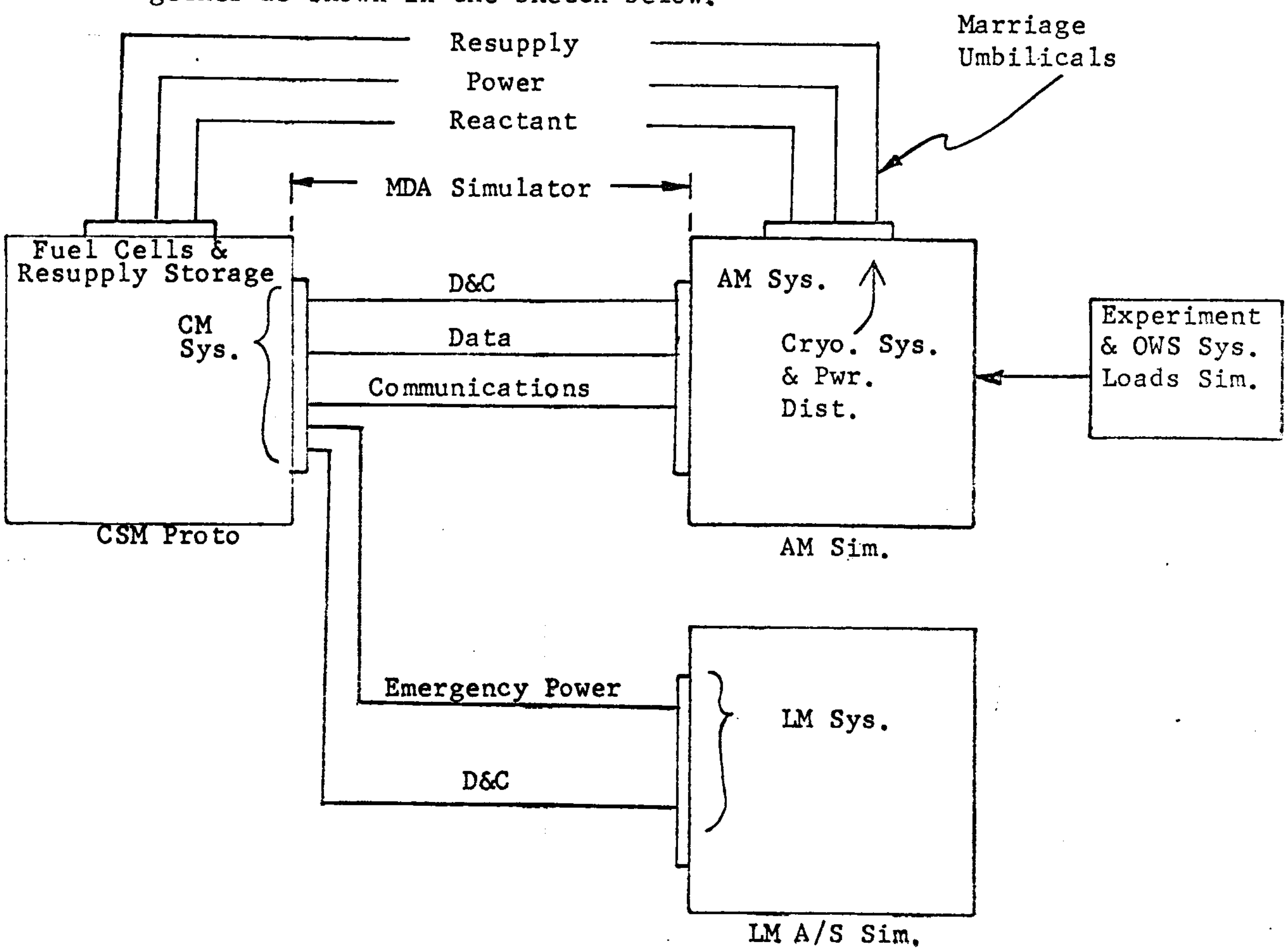
Legend:

*	Shipped off site for thermal vacuum testing
**	Simulators are described in Appendix A by simulator item number
A	Assumed
B	NASA Directive
C	Known Trainer
D	Flight Article

Figure 12. Test Hardware Matrix

3.2 Simulator Requirements Summary - Figure 13 presents a summary of the simulator requirements in tabular form. As an example of the use of the figure, consider the first three lines which identify the simulator requirements for the CSM tests at NAA.

Line three shows the MDA simulator. The X in the "MDA through connection simulation" column indicates that the MDA simulation is basically a through connection with line drops and attenuation, etc., consistent with the flight MDA. The actual functional components are in the AM and LM A/S, and consequently, the AM, MDA and LM A/S simulators must be used together as shown in the sketch below.



The following notes are referenced on Figure 13:

Note 1 - LM simulators will include ATM functions that interface via LM or that are reflected across the LM-CM interface.

Note 2 - Resupply capability is assumed to be located in a sector of the SM. Transfer is assumed to be by EVA connected AM-SM external umbilicals.

Note 3 - This two part simulator will provide through connections only. Part two will consist of a partial axial docking port, including aids.

Note 4 - Simulation of varying experiment loads (MDA & OWS operating (experiments) reflected on the SM power source (fuel cells) via the AM distributor. Simulation of S027 experiment (carried in IU of AAP 3) required to checkout CM display and control.

Note 5 - Simulates the CSM power, communication, and D&C.

Note 6 - The MDA is a two part simulator. Part one simulates through connections. Part two is a partial axial docking port including docking aids.

Note 7 - Partial rack mockup must provide precision simulation of rack attachment surfaces and technique. Forward portion in vicinity of interface must be representative of rack size and shape for fit and clearance checks. Some rack components may require mockup for interference checks.

Note 8 - CM simulation of display and control for S027 experiment checkout. Must include characteristics of cable from CM to IU via SM and SLA (line drop, etc.).

Note 9 - Forward S-IVB partial mockup to facilitate flight 4 launch configuration fit and clearance checks (same one as provided for flight 2 checks).

Note 10 - Experiment simulators required during ATM qualification and design verification if prototypes are not provided by the developer. Size and shape not required. Simulator item 23 will satisfy fit and clearance check requirements.

Note 11 - LM A/S partial mockup must be representative of size, shape and attachment point (for fit and clearance check) and must be representative of weight and CG for dynamic testing of the ATM structural model and flight article.

Note 12 - Non-functional simulation of the LM thermal transfer characteristics at the ATM rack interface.

Note 13 - Simulation of D&C, power distribution, communications and capability for accepting EDS fluids to simulate ATM rack storage depletion (this simulation may be part of ATM checkout GSE) not required for thermal model test.

Note 14 - Sufficient portion of solar panels (stubs) to provide representative shadowing on ATM. Must be strong enough to be deployed in one "G" or must have supplemental support.

Note 15 - Component and experiment conducted and radiated thermal characteristics simulation to be used with the ATM thermal model for development tests.

Note 16 - Component and experiment mockups for dynamic testing on ATM structural model. Must be representative of attachment method, weight and CG.

Figure 13 Simulator Requirements Summary Sheet 1

HARDWARE AVAILABILITY				SIMULATION REQUIREMENTS			FUNCTIONAL SIMULATION										PHYSICAL SIMULATION							
CENTER RESPONSI-BILITY	LOCATION	FLIGHT ARTICLES	PROTOTYPES	SIM. ITEM NO.	SIMULATION OF	REQUIRED FOR TEST OF	POWER	DATA	COMMUNICATIONS	ECS/LS ELECT.	THERMAL CONTROL	PROPULSION	G&N	D&C	FLUIDS/GAS	THROUGH CONN.	DOCKING PROVISION	ATTACH POINTS	SIZE SHAPE	WEIGHT, CG	RF REFLECTIVITY	COMP. MOCK UP	CONN. MATE CAPABILITY	NOTES
MSC	NAA	CSM SLA	CSM Prototype (A)	24	LM A/S	CSM modification design verification. Flight CSM acceptance	X							X									X	1
				25	AM		X	X	X					X	X								X	2
				26	MDA											X	X						X	3
				27	Exp. Sim.		X	X						X									X	4
	Grumman	LM A/S	LM A/S Prototype (A)	28	ATM	LM A/S modification design verification. Flight LM A/S acceptance	X	X	X	X				X	X								X	
				29	CSM		X		X					X									X	5
				30	MDA										X		X						X	6
				31	AM		X		X															
				32	Rack													X	X			X		7
MSFC	IBM	IU	Flight IU (D)	39	CM D&C	S027 experiment modification checkout								X									X	8
	MSFC	ATM	ATM Prototype (B) ATM Struct. Unit (B) IU Structure (A) SLA Prototype (A)	33	Solar Power	ATM Design verification. Flight ATM acceptance	X																	
				34	S-IVB Partial Mockup														X					9
				35	LM A/S		X	X	X	X				X	X								X	
				36	Exp. Sim.			X	X					X									X	10
				37	LM A/S Partial Mockup													X	X	X				11
				38	Component & Experiment Mass Properties													X	X	X			X	16

Figure 13 Simulator Requirements Summary Sheet 2

HARDWARE AVAILABILITY				SIMULATION REQUIREMENTS			FUNCTIONAL SIMULATION										PHYSICAL SIMULATION							
CENTER RESPONSI-BILITY	LOCATION	FLIGHT ARTICLES	PROTOTYPES	SIM. ITEM NO.	SIMULATION OF	REQUIRED FOR TEST OF	POWER	DATA	COMMUNICATIONS	ECS/LS ELECT.	THERMAL CONTROL	PROPULSION	G&N	D&C	FLUIDS/GAS	THROUGH CONN.	DOCKING PROVISION	ATTACH POINTS	SIZE SHAPE	WEIGHT, CG	RF REFLECTIVITY	COMP. MOCK UP	CONN. MATE CAPABILITY	NOTES
MSFC (cont)	Off-Site Thermal Vacuum Chamber	ATM	ATM Thermal Unit (B) ATM Prototype (B)	40	LM A/S Thermal Simulator	Thermal vacuum test of ATM Thermal Unit, prototype and flight ATM																		12
				41	LM A/S Functional Simulator		X	X	X	X				X	X								X	13
				42	Solar Panel Stubs													X	X					14
				43	Component & Exp. Thermal Sim.													X						15
KSC	KSC	CSM ATM SLA Nose Cone IU LM A/S S-IVB	None	44	MDA	Prelaunch Checkout Flights 3 and 4										X							X	
				45	AM		X	X	X					X	X									
				46	S-IVB Experiment & System Loads		X	X	X						X									

3.3 Evaluation - The ability of this test program to satisfy inter-carrier and cluster compatibility verification has been evaluated against a specific set of requirements. This evaluation is presented in Figure 20.

Figures 14 through 19 illustrate the various test configurations that can be achieved in each test location.

The complexity of the carrier interfaces is illustrated in the data contained in Appendix. B.

3.3.1 General Evaluation - Utilizing the hardware assumed to be available at the various locations, adequate design verification can be accomplished on the individual carriers of flights 3 and 4.

While extensive modifications will be required on the CSM to facilitate the resupply functions that were originally assigned to a separate resupply module, the test program should provide adequate verification of the CSM modification design. It should be noted that this study is based on the use of a flight configured CSM prototype at NAA for qualification and design verification.

It is felt that this approach is mandatory due to the extensive modifications to sector 1 of the SM. If the resupply function were provided by a separate module, the concept of qualifying and verifying the design on the flight CSM might be feasible.

With the exception of the S027 experiment which is installed in the IU and has D&C provisions in the CM, there are no inter-carrier test requirements on flight 3. Adequate verification of this requirement is satisfied by NAA tests on the CM using an S027 experiment simulator; at IBM using a CM display and control simulator, and at the launch pad where the flight CM display and control is mated with the flight experiment via the SLA cable harness.

No launch configuration design verification test requirements are envisioned for flight 3.

Individual design verification testing on the ATM and the LM A/S appears to be adequate based on the assumption that an ATM thermal model, an ATM vibration unit and a complete flight configured prototype is provided. Due to the extent of modifications on the LM A/S, it is assumed that a flight configured LM prototype will be used by Grumman for design verification testing.

The ability to verify flight 4 inter-carrier design compatibility is questionable. Testing at MSFC and the off-site thermal vacuum chamber makes use of LM simulation while the Grumman test activities use an ATM functional simulator and rack mockup. Valid compatibility verification cannot be accomplished at these locations.

The flight LM A/S and ATM will be mated and checked out at KSC during prelaunch checkout. The extent of design verifications that can be accomplished on the flight hardware, however, is limited in the areas of parametric testing, contingency planning verification, and automatic corrective actions. There is also the added risk of detecting a design incompatibility during prelaunch checkout which would result in severe schedule impact.

Flight 4 launch configuration verification can be accomplished at MSFC using the S-IVB partial mockup, the IU structural shell and the SLA prototype provided for flight 2 testing, the ATM prototype, and the LM partial mockup.

The direct CSM to LM A/S interface compatibility (docked mode) cannot be adequately verified until KSC since both NAA and Grumman will use interface simulation. Fairly complete verification can be accomplished at KSC during prelaunch checkout. Again there is some risk involved in late detection of an incompatibility. However, probability is low since the AAP modifications have little effect on the basic CSM to LM interface and the standard CSM-LM compatibility will have been demonstrated by the Apollo program prior to flight 4 of the AAP program.

The major risk in this test program, as well as the flight 1/2 test program, is the inability to verify cluster compatibility.

Sector 1 of the flight 3 SM will be modified to provide the resupply capability for the cluster during the extended duration mission. This resupply will be accomplished via external umbilicals to the AM storage vessels. One of the most significant risks involved in this program is the inability to verify CSM to AM compatibility and commodity transfer techniques. While the CSM tests at NAA will use an AM simulator, the first flight configured hardware mating will occur on orbit. Similarly, the first attempt at transferring critical commodities through a fully flight configured system will occur when resupply of the cluster is required on orbit.

This condition exists because, by ground rule, there is no fully flight configured AM prototype provisioned for the flight 1/2 test program. The flight AM will be on orbit before the flight 3 SM modifications are ready for test. Consequently, no flight configured AM is available for SM compatibility verification.

Similarly, compatibility between CSM 3 and the OWS, MDA and AM in the areas of communications, data systems and display and control cannot be verified. While this condition is obviously undesirable, the risk is not as severe as the resupply problem. Indications are that the differences between CSM 1 and CSM 3 in the areas of data, communications and D&C interfaces with the cluster are not extensive. Design verification on flight 1 CSM should provide confidence in the design compatibility of CSM 3.

LM A/S to MDA direct interfaces cannot be verified, however, the extent of the interface appears to be relatively small consisting of an emergency power provision and some D&C.

The cluster configuration compatibility cannot be verified in the areas of EMC, ground-on orbit compatibility, FMECA and contingency planning verification, man-machine compatibility, and cluster mission simulation.

While some level of confidence may be acquired through extensive analysis supplementing the results of the flight 1/2 and flight 3/4 test programs, the complexity of the cluster systems would appear to make this approach invalid, or at best, questionable. This is especially true when considering the potential EMC problems that could be generated by the radiation of the numerous antenna systems shown in Appendix B. Neither the flight 1/2 nor the flight 3/4 provide for a full or partial cluster test in an on orbit orientation to determine the effects of RF reflection, antenna pattern overlap and intermodulation. Attempts to determine these effects by analysis is not feasible.

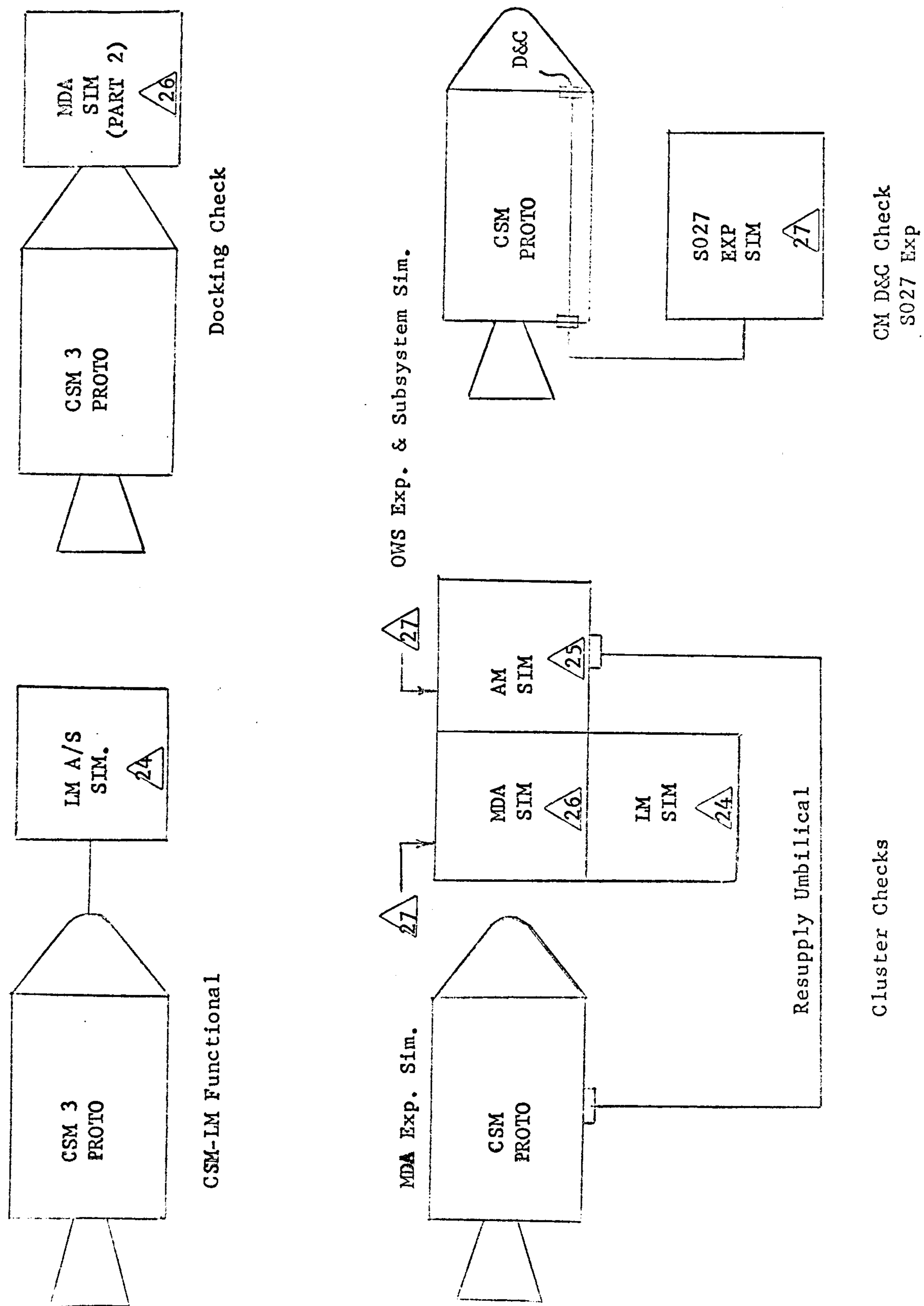


Figure 14. NAA Test Configurations

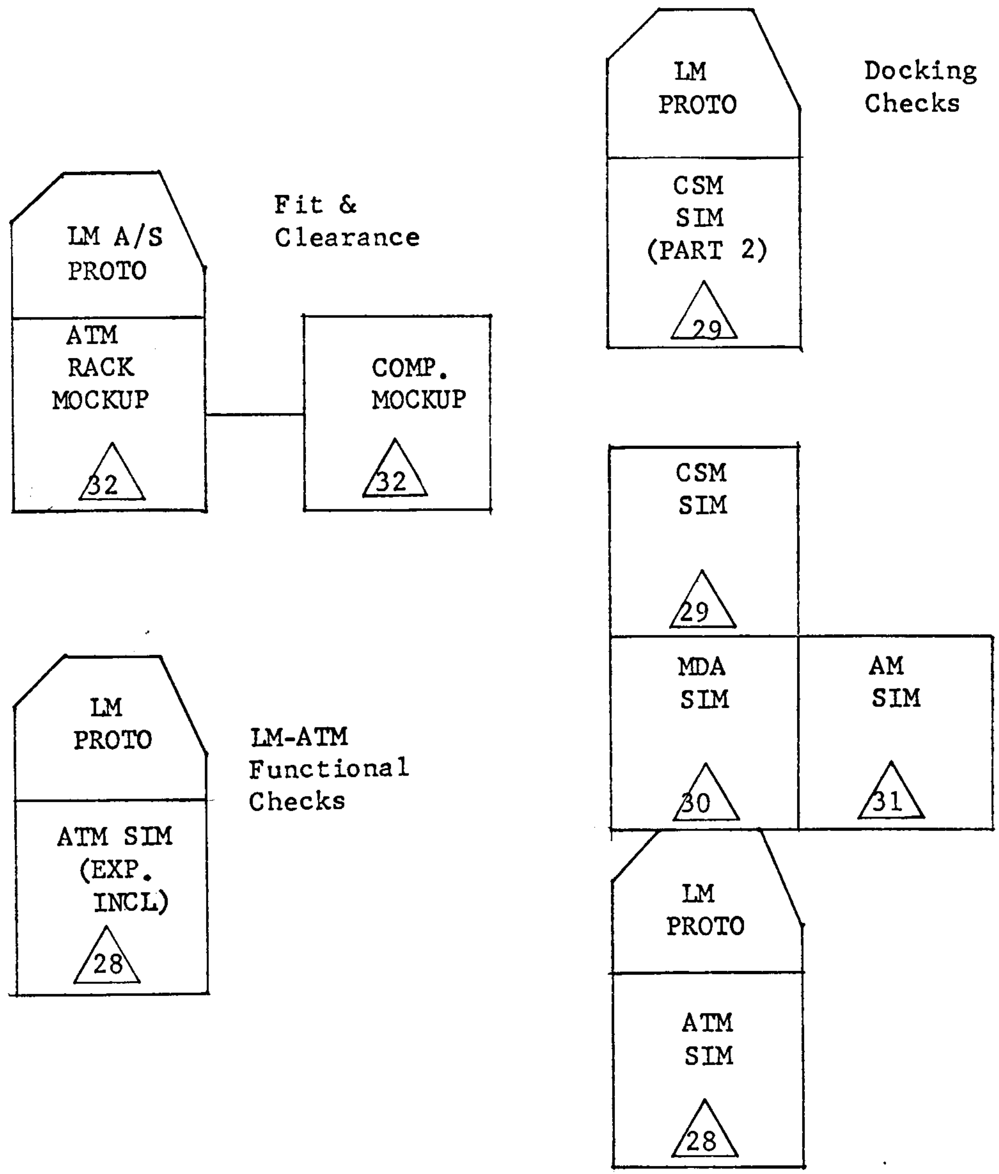


Figure 15. Grumman Test Configurations

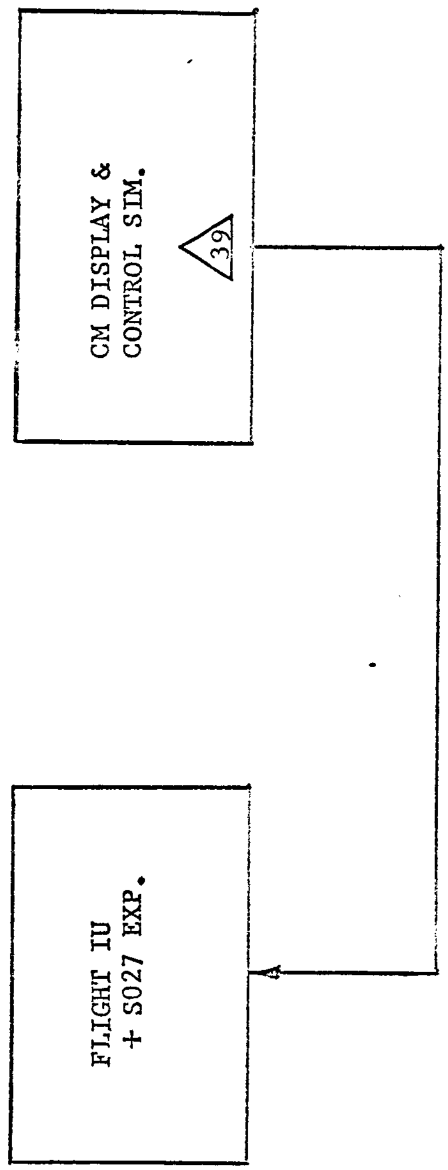


Figure 16. IBM Test Configuration

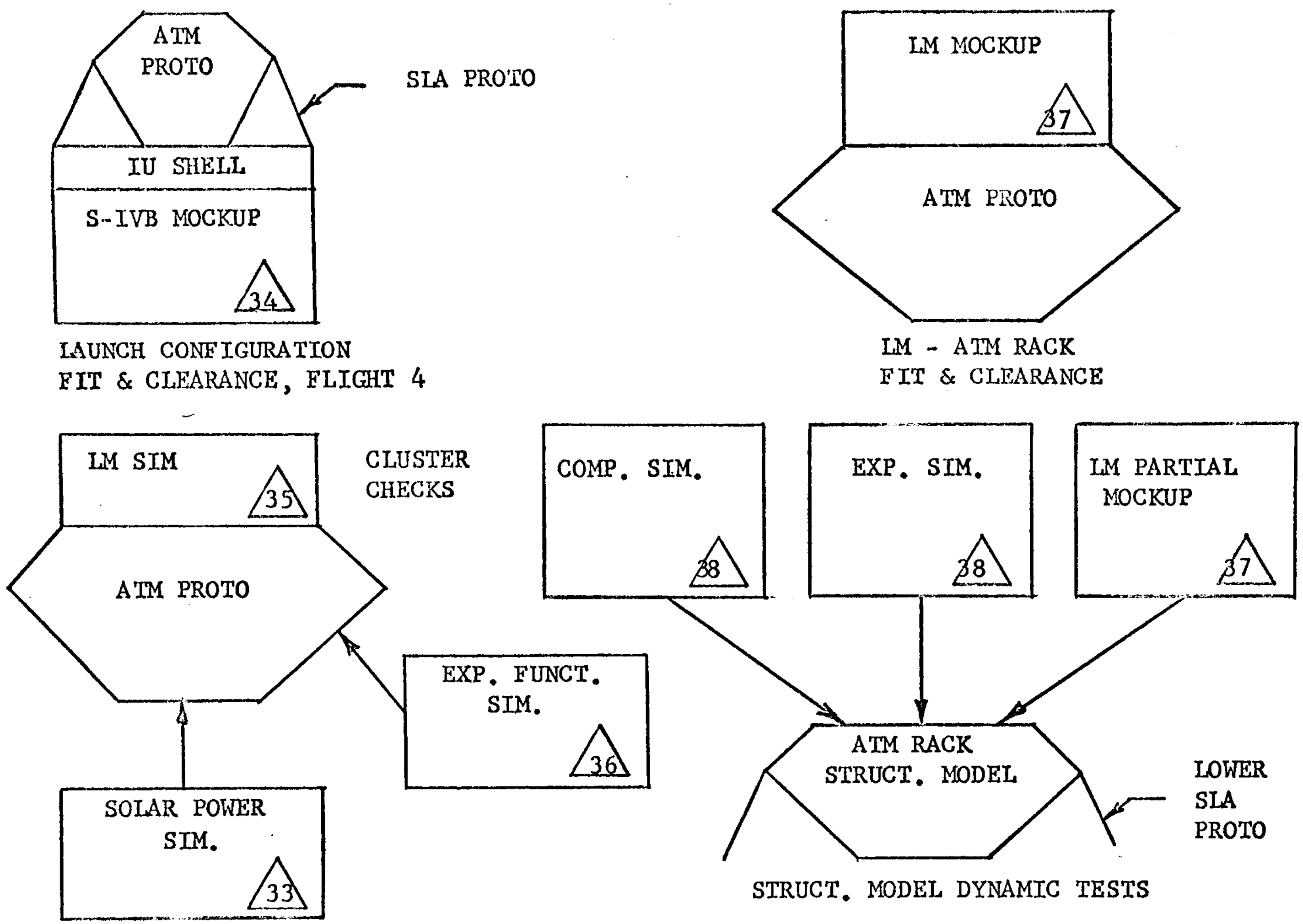


Figure 17. MSFC Test Configurations

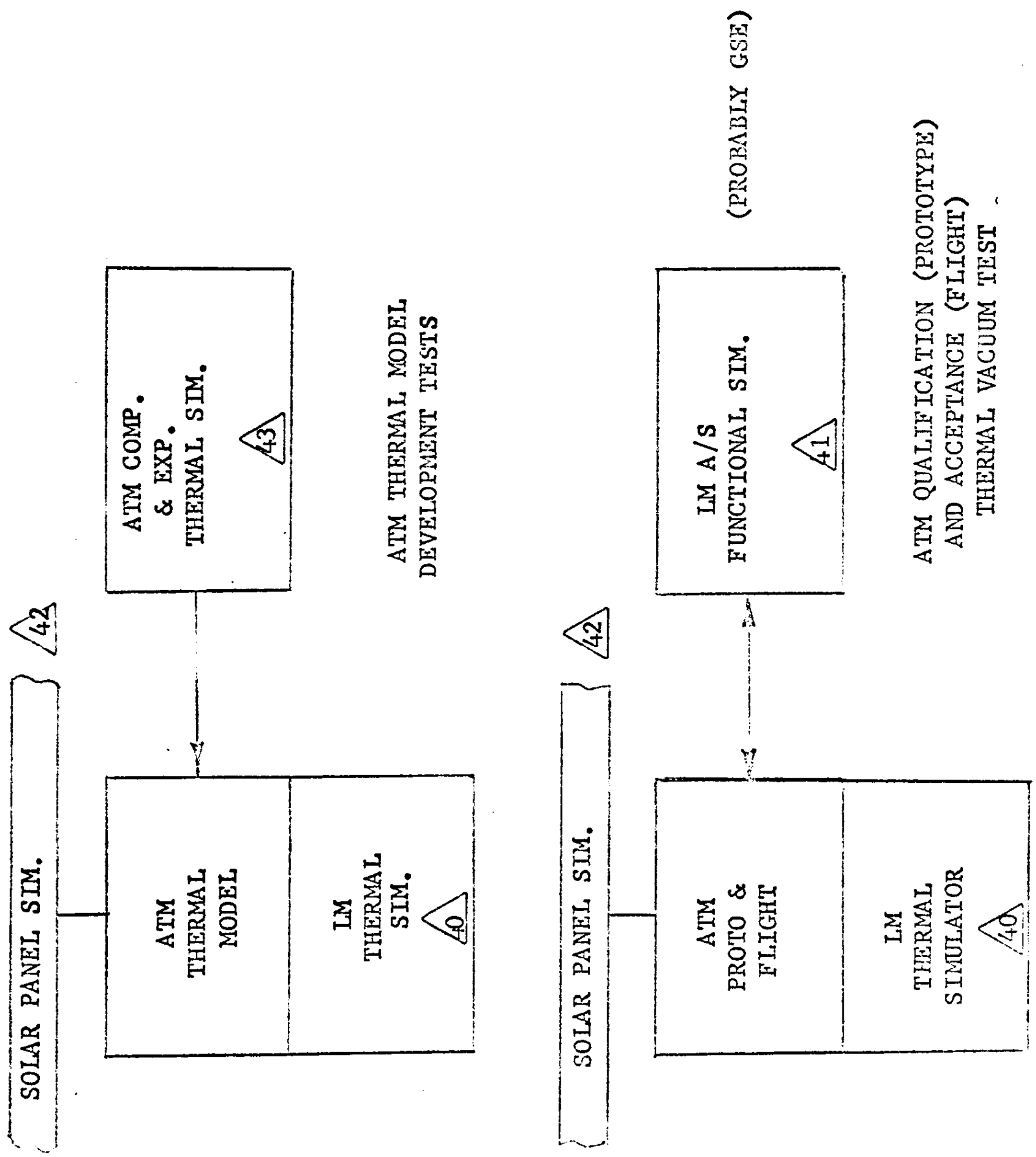


Figure 18. Off-Site Thermal Vacuum Chamber

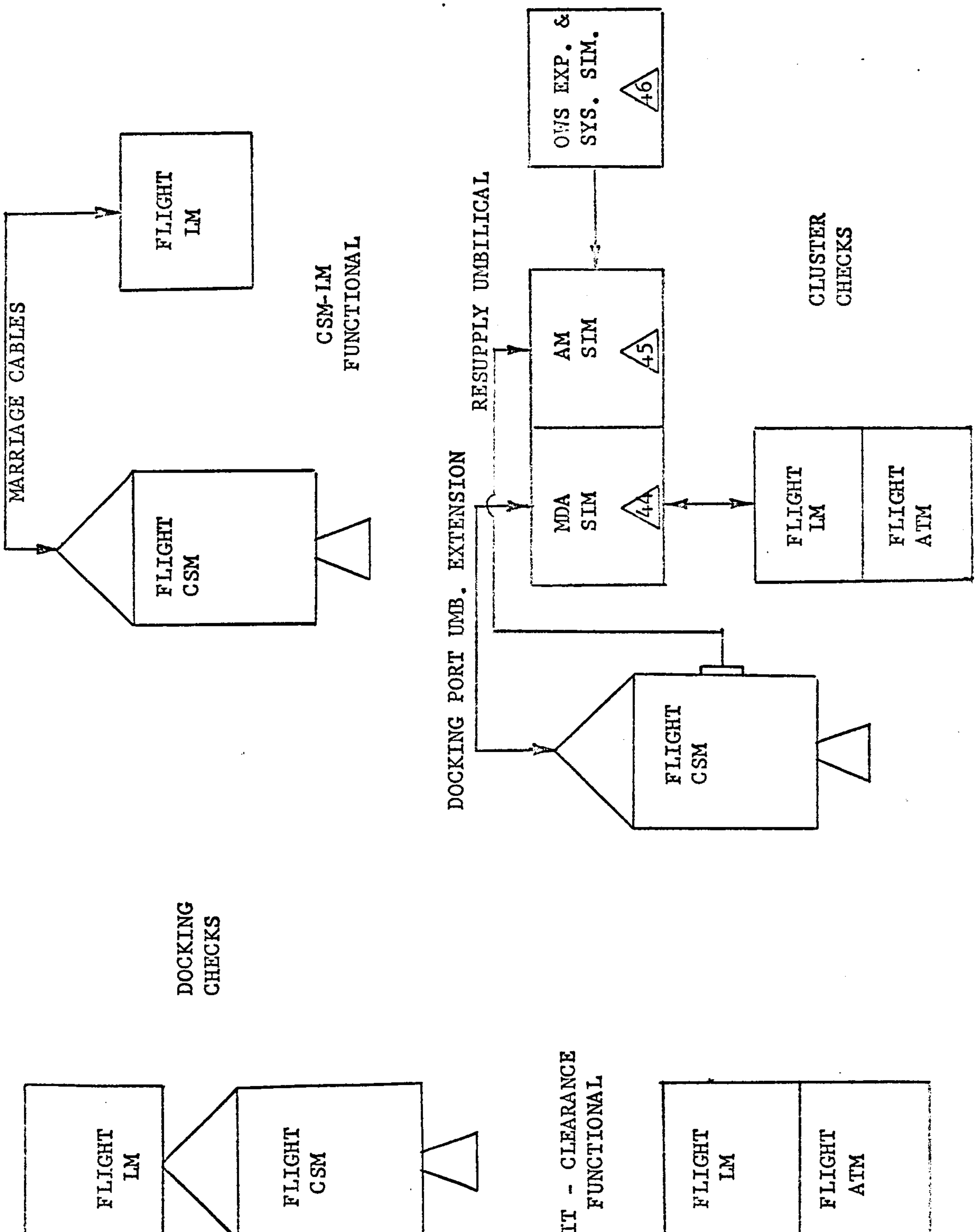


Figure 19. KSC Test Configurations

3.3.2 Evaluation Against Specific Requirements - The following sheets provide an evaluation of the test program against more specific test requirements (Figure 20).

The first column identified a specific test requirement. The next eight columns indicated the location where testing of this requirement may occur, but does not necessarily indicate that any one location or combination of locations, satisfy the requirement completely.

The next column assigns an evaluation figure to the ability of the test program to satisfy that requirement. Ratings are in descending order from 10 to 1 with 10 being high. The meaning of the ratings can be grouped into three categories as follows:

1-4 indicates that the test requirement cannot be satisfied by this program and that a relatively high risk factor is involved.

5-7 indicates that the test program is marginal in this area. The significance of this rating would probably be influenced by the extent and quality of supplemental engineering analysis but confidence in design compatibility would probably be lower than desirable.

8-10 indicates that the test program appears to be adequate in this area and should provide sufficient test verification.

The final column provides a brief rationale for the evaluation rating assigned in the preceding column.

TEST REQUIREMENT	TEST AREA: NAA	GRUM.	IBM	MSFC	OFF SITE	KSC	EVALUATION RATING	EVALUATION RATING JUSTIFICATION
Communications, ATM								
1. Data compatibility with LM A/S transmitter & recorder				X		X	10	Complete verification at KSC on flight hardware.
Display and Control, CSM								
1. Compatibility with MDA sensors	X					X	5	Cannot be verified due to MDA simulation at all areas, however, Flight 1 CSM checks with MDA should establish some confidence in design compatibility if CSM 1 and 3 are similar.
2. Compatibility with AM sensors via MDA	X					X	4	Same as above
3. Compatibility with OWS sensors via AM/MDA	X					X	3	Same as above
4. Compatibility with IU (Exp. S027)	X					X	7	Verification of flight hardware at KSC will be delayed until launch pad. Checkout will be limited to ambient readout of experiment.
Display and Control, IU								
1. Compatibility with CM (Exp. S027)			X			X	7	Same as above

Figure 20. Detailed Evaluation

TEST REQUIREMENT	TEST AREA NAA	GRUM.	IBM	MSFC	OFF SITE	KSC	EVALUATION RATING	EVALUATION RATING JUSTIFICATION
ATM, Fluid								
1. LSS compatibility with LM A/S (source in rack)				X	X	X	9	Limited verification at MSFC using LM simulation under ambient environment with additional confidence established by off-site thermal vacuum testing. Checks at KSC on flight hardware (gas in lieu of cryogenics caused some de-rating).
Communications, CSM								
1. Voice compatibility with LM A/S (direct docked CSM-LM mode)	X					X	10	Complete verification possible at KSC on flight hardware.
2. Voice compatibility with AM	X					X	7	AM will be simulated at NAA and KSC. However, it is assumed that CSM 1 and 3 will be identical in area of communication and design compatibility should be proven on Flight 1 and 2.
3. Voice compatibility with OWS	X					X	5	This compatibility was not proven between CSM 1 and OWS and cannot be proven between CSM 3 and OWS. Results of Flight 1 and 2 on orbit compatibility should be demonstrated before flight 3 launch.

Figure 20. Detailed Evaluation

TEST REQUIREMENT	TEST AREA NAA	GRUM	IBM	MSFC	OFF SITE	KSC	EVALUATION RATING	EVALUATION RATING JUSTIFICATION
Communications, CSM (continued)								
4. Voice communications with EVA, all potential interference operating	X					X	2	Very limited capability at NAA (no interference sources). No capability at KSC due to test orientation (CSM in chamber, LM/ATM outside. Remainder of cluster simulated).
5. Data communications with OWS (TV monitor via AM/MDA	X					X	6	Very limited verification at NAA and KSC. However, CSM 1 to OWS checkout should provide some confidence in CSM 3 to OWS compatibility.
Communications, LM A/S								
1. Voice compatibility with CM		X				X	9	Complete verification possible at KSC degraded only by extension umbilicals for side by side operation.
2. Data compatibility with ATM end instruments (recorder and transmitter in LM)		X				X	10	Complete verification at KSC on flight hardware.
3. Switching compatibility ATM data recorder to real time transmission		X				X	10	Complete verification at KSC on flight hardware.

Figure 20. Detailed Evaluation

TEST REQUIREMENT	TEST AREA: NAA	GRUM.	IBM	MSFC	OFF SITE	KSC	EVALUATION RATING	EVALUATION RATING JUSTIFICATION
ATM Rack Power System								
1. Compatibility with LM distributor				X		X	8	Limited verification at MSFC with LM simulator. Adequate verification at KSC using solar power simulation with flight ATM and LM.
2. Switching compatibility from SM 3 power to internal power				X		X	7	Adequate checkout at KSC, however, de-rated due to simulation of ATM solar power and SM fuel cells.
3. Switching compatibility from internal to CSM 3 via MDA distributor (emergency)				X		X	5	Checks at KSC de-rated due to simulation of AM/MDA distributor switching, solar power and fuel cells.
4. Mission sequence compatibility				X		X	7	Checks at MSFC would not have high value due to extensive simulation. KSC checks should be adequate but late in test cycle. Parametrics and contingency testing limited.
Fluids, CSM								
1. Resupply compatibility with AM via external umbilicals	X					X	3	Checks at NAA and KSC will use AM simulator. No mating of a flight configured SM and AM will occur until on orbit. Major SM modification in the area of resupply.
2. Compatibility with LM life support (emergency)	X					X	8	Adequate verification between NAA (LM simulation) and KSC (flight LM and CSM).

Figure 20. Detailed Evaluation

TEST REQUIREMENT	TEST AREA: NAA	GRUM.	IBM	MSFC	OFF SITE	KSC	EVALUATION RATING	EVALUATION RATING JUSTIFICATION
Fluids, LM								
1. LSS compatibility with AM or SM via MDA		X				X	4	Simulation of AM at Grumman and KSC. Verification of flight configured hardware occurs on orbit only.
2. LSS compatibility with SM via CM (docked LM to CSM mode)		X				X	9	Valid verification can be accomplished on flight LM and CSM at KSC.
3. Mission sequence compatibility			X			X	8	KSC should be able to provide adequate mission simulation, however, some de-rating due to simulation of AM/MDA.
Power, SM System								
1. Compatibility with ATM/LM (docked AAP 3/4)	X					X	8	Limited verification at NAA and KSC due to AM/MDA simulation. CSM 1 to MDA/AM checks during Flight 1 and 2 checkout will establish some level of design confidence depending on extent of differences between CSM 1 and 3 in area of power.

Figure 20. Detailed Evaluation

TEST REQUIREMENT	TEST AREA: NAA	GRUM.	IBM	MSFC	OFF SITE	KSC	EVALUATION RATING	EVALUATION RATING JUSTIFICATION
<u>Power, SM System</u> (continued)								
2. Compatibility with AM/MDA distributor feeding OWS and emergency LM.	X					X	7	Limited verification at NAA and KSC due to AM/MDA simulation. CSM 1 to MDA/AM checks during Flight 1 & 2 checkout will establish some level of design confidence depending on extent of differences between CSM 1 and 3 in area of power.
3. Switching and isolation compatibility between SM and ATM solar power and S-IVB solar power	X					X	7	Same as above.
4. Mission sequence compatibility with all systems						X	5	Attempts at complete mission sequence check at NAA would be practically valueless due to extensive simulation. KSC checks will be marginal due to AM/MDA simulation.
<u>Inter-Carrier Functional Compatibility</u>								
1. CSM-LM all systems compatibility (docked CSM-LM Mode)	X	X				X	8	Adequate verification at KSC on flight hardware but limited in parametric testing.

Figure 20. Detailed Evaluation

TEST REQUIREMENT	TEST AREA: NAA	GRUM.	IBM	MSFC	OFF SITE	KSC	EVALUATION RATING	EVALUATION RATING JUSTIFICATION
Inter-Carrier Functional Compatibility (continued)								
2. Flight 1/2/3/4 mission sequence compatibility (cluster)	X	X		X		X	4	Limited capability at NAA, Grumman and MSFC. Partial cluster type testing at KSC with flight 1 and 2 elements simulated. No mating with flight configured hardware elements of flight 1 and 2 until on orbit.
3. Cluster EMC compatibility	X	X		X		X	3	Very little verification possible at NAA, Grumman and MSFC. No RF compatibility verification at KSC due to checkout orientation. Some purely EM compatibility possible (grounding, shielding, etc.) but validity questionable due to marriage cables and umbilical extensions plus simulation of flight 2 elements.
4. Flight 3 launch configuration functional verification						X	8	Verification at KSC on launch pad limited by ambient experiment S027 operation.
5. Flight 4 launch configuration functional compatibility						X	8	Verification at KSC should be adequate.
6. Man-Machine compatibility Flight 3/4	X	X				X	6	Verification at KSC limited by orientation of carriers and constraints of operation in one "G" environment.

Figure 20. Detailed Evaluation

TEST REQUIREMENT	TEST AREA: NAA	GRUM.	IBM	MSFC	OFF SITE	KSC	EVALUATION RATING	EVALUATION RATING JUSTIFICATION
<u>Inter-Carrier Functional Compatibility</u> (continued)								
7. Cluster man-machine compatibility-re-activation, experiment operations, EVA, time line verifications						X	3	Verification limited by orientation, operation in one "G", extensive simulation of flight 2 elements. No complete cluster achieved until on-orbit.
<u>Structural-Mechanical Compatibility</u>								
1. CSM 3 to MDA docking							7	Cannot be verified, however, if CSM 1 and 3 are identical in area of docking and docking aids, sufficient confidence should be established by flight 1 and 2 checks.
2. ATM to SLA fit and clearance				X		X	10	Complete verification at MSFC using SLA prototype and at KSC using flight hardware.
3. LM to CSM 3 docking including docking aids	X	X				X	10	Master gauge or simulator checks at NAA and Grumman. Docking check at KSC on flight LM and CSM.
4. Cluster configuration clearance and access verification							4	Cannot be verified, however, some confidence will be established via mockup and scale model checks.

Figure 20. Detailed Evaluation

TEST REQUIREMENT	TEST AREA: NAA	GRUM.	IBM	MSFC	OFF SITE	KSC	EVALUATION RATING	EVALUATION RATING JUSTIFICATION
<u>Contingency Planning & FMECA Validation</u>								
1. Verification of cluster failure mode effects analysis							2	No valid verification can be achieved in any area. Some confidence may be established by analysis supplementing individual carrier testing.
2. Verification of cluster systems automatic corrective actions							4	Some verification can be achieved at KSC limited by constraints imposed on ability to disable redundant systems on flight hardware (potentially detrimental) and extensive simulation requirement.
3. Verification of alternate experiment grouping analysis	X	X	X	X		X	5	Feasibility can be demonstrated on individual carriers. Effects of alternate groupings on cluster systems in terms of functional compatibility, EMC verification, man-machine cannot be demonstrated.
4. Emergency procedure verification, Flight 3	X					X	8	Adequate demonstration at NAA and KSC.
5. Emergency procedure verification, flight 3/4 (CSM - LM/ATM)	X	X		X		X	6	Verification at NAA, Grumman and MSFC limited by simulation. Checks at KSC limited by use of flight hardware (extent of malfunction simulation limited).

Figure 20. Detailed Evaluation

TEST REQUIREMENT	TEST AREA: NAA	GRUM.	IBM	MSFC	OFF SITE	KSC	EVALUATION RATING	EVALUATION RATING JUSTIFICATION
<u>Contingency Planning & FMECA Validation</u> (continued)								
6. Emergency procedure verification cluster						X	4	Cannot be verified, however, analysis of Flight 1 and 2 tests coupled with results of individual testing on Flight 2 and 4 elements may establish an acceptable level of confidence.
<u>Ground-Orbit Compatibility Verification</u>								
1. Flight 3 compatibility ground crew operations	X					X	9	Adequate verification between NAA and KSC testing.
2. Flight 3/4 compatibility (LM-CSM)	X			X		X	9	Adequate verification at KSC.
3. Cluster compatibility	X	X		X		X	5	Cannot be adequately verified due to extensive simulation of Flight 2 elements at all locations.
<u>Ground Control and Monitor</u>								
1. Cluster compatibility with tracking stations and mission control						X	3	Cluster compatibility cannot be verified. Cluster orientation cannot be achieved. Antenna masking evaluation not possible. RF interference, RF reflectivity, intermodulation effects cannot be verified.

Figure 20. Detailed Evaluation

4. CONCLUSIONS

4.1 Flight 1/2 - The program described in this report is weak in many areas and will provide less than desirable confidence in on-orbit compatibility.

The individual qualification and design verification of the Flight 1 carriers is adequate.

The Flight 2 test program is hindered by the lack of a flight configured prototype AM and MDA and Flight 2 inter-carrier design verification testing at KSC will be limited by the use of flight carriers.

Inter-flight testing between carriers of Flights 1 and 2 can only occur at KSC and again is limited by the use of flight carriers. In addition to the technical risks involved, the possibility of detecting a design incompatibility at KSC within three months of launch presents a real risk of individual launch date slippage and total program schedule impact.

While the Flight 1/2 test program is weak, the most severe problem is not readily evident, namely, the inability to verify total cluster 1/2/3/4 interface design compatibility.

4.2 Flight 3/4 - The Flight 3/4 test program in this report is weak in many areas and will provide less than desirable confidence in on-orbit compatibility.

As in the flight 1/2 test program, the qualification and design verification of individual flight 3 and 4 carriers seems adequate.

Interflight testing (LM-CSM) can only occur at KSC on flight hardware and the design compatibility verification is weakened by constraints imposed on testing of flight hardware. In addition, the risk of discovering a design incompatibility at KSC could create severe schedule impact.

While LM-ATM compatibility can be verified to some extent at KSC, again the use of flight hardware will limit the extent of design verification. Cluster compatibility cannot be verified and the first verification of most cluster compatibility requirements will be accomplished on orbit.

It is evident from the evaluation of this program and the previous evaluation of the flight 1/2 program that the risk of complete or partial failure to achieve mission objectives will be high if a test program of this nature is implemented.

4.3 Recommendations - While the test programs evaluated cannot provide the level of confidence that could be achieved through the use of a full cluster design verification test, it is felt that implementation of the following recommendations would greatly improve the alternate test programs.

a. Provide a full flight configured prototype AM and MDA which would not only facilitate a more adequate flight 1/2 test program but would also establish a means for verifying compatibility between elements of flight 1/2 and flight 3/4. This would provide a means for verifying compatibility between the SM resupply modification and the AM, eliminating one of the more significant weaknesses of the program. Mated AM-SM testing could be accomplished either at NAA or MAC.

b. Perform a mated AM/MDA design compatibility test using the flight configured prototypes either at MSFC or at MAC. This requirement has become more significant in recent weeks as the complexity of the MDA increased from a basically static interface adapter to an active carrier. The requirement to operate numerous experiments within the MDA and the addition of active experiment support subsystems has changed the relationship between the AM and MDA.

c. Perform a mated LM A/S and ATM flight configured prototype test at either MSFC or Grumman. The interface between these two elements (approximately 1200 wires including redundancy) is not a simple interface and the concept of performing the first mate of flight configured LM and ATM at KSC would appear to present an unacceptable risk in terms of potential total program schedule impact. In addition, it is felt that since the LM is a manned carrier, it is extremely important that calculated design safety margins be verified by parametric and off limits testing which cannot be performed on flight hardware.

The main area of concern with respect to verifying design margins for added confidence in crew safety is the power interface. The power source is the solar panel and battery system on the ATM which feeds the LM distributor. A design incompatibility in this area or an erroneous design safety margin calculation could result in a condition hazardous to the LM crew member.

This report has provided a first look at the gross simulator requirements for the program, identifying only the major simulator elements. It is obvious that many additional but less costly simulators will be required to support this program. It is recommended that the identification of simulators be further pursued and that the identified simulators be better defined in terms of complexity.

Two additional factors should be evaluated - cost and schedules. No attempt has been made to evaluate the cost of simulators identified. This effort cannot be attempted until the simulation requirements are defined in greater detail. While a gross program schedule has been provided, the simulator design and build schedules have not been established.

Appendix A - Simulator Descriptions

Two categories of simulation are considered in this appendix: "Design Specification Interface Simulators (DSI)", and "Carrier Simulators".

Design Specification Interface Simulators (DSI)

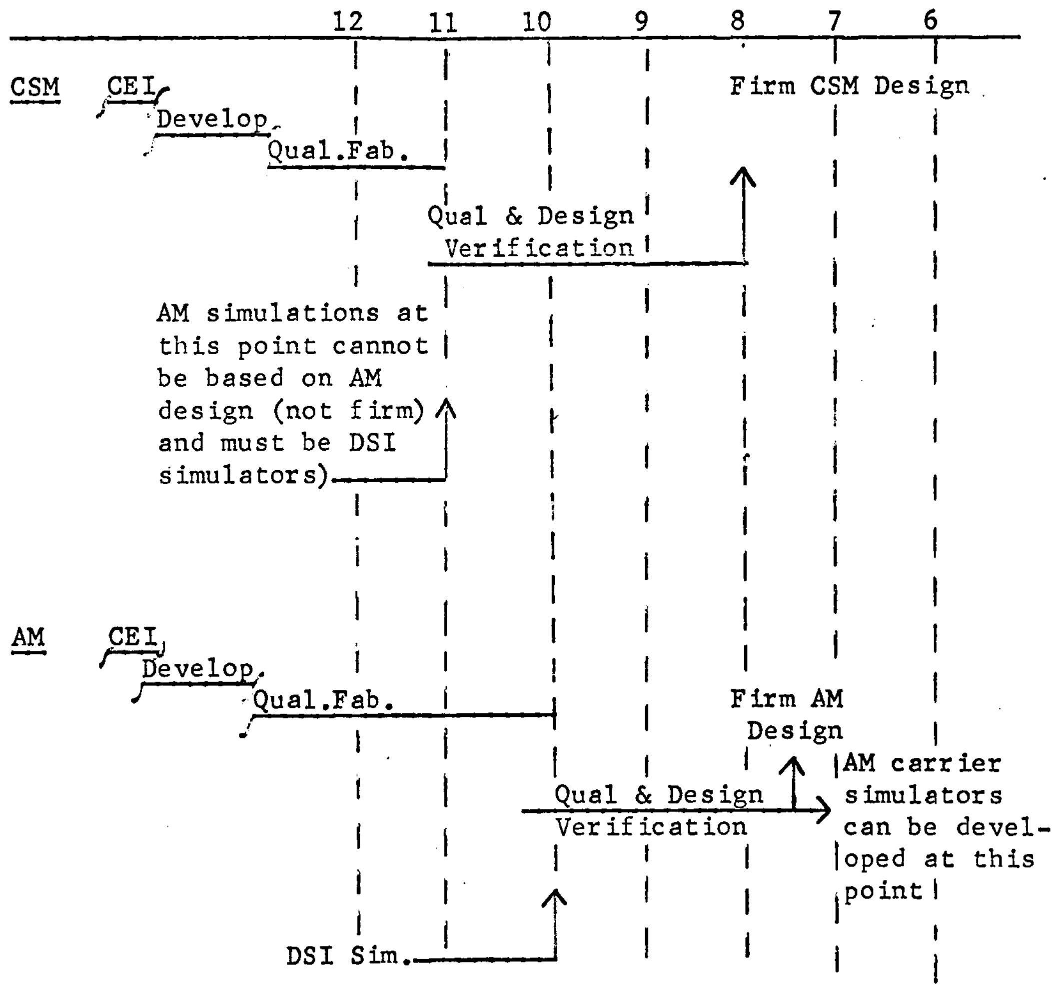
DSI simulators will be provided at the various carrier conrractor facilities to support design verification, qualification, and acceptance testing of individual carriers. These simulators will represent the total interface as "seen" by the carrier under test. They will simulate the parameters of the carrier design specification, and may not be representative of the interfacing carriers to any extent. They will have the capability of verifying tolerance extremes as well as nominal values.

Carrier Simulators

In the absence of a cluster test program, inter-carrier and cluster compatibility can only be verified to a limited degree. This verification must be performed at KSC using flight hardware supplemented by complex carrier simulators.

The carrier simulators will be representative of the actual flight hardware to the maximum extent possible. They may even employ actual flight components and systems, and configuration will be representative of flight hardware.

One of the most severe problems associated with a test program of this nature is the inability to provide "carrier simulators" during individual carrier tests due to concurrent development of carriers. Consider the CSM and AM schedules as shown below:



A carrier simulator (representative of the AM) cannot be provided for the CSM prototype testing.

Instead, the CSM is tested against a DSI simulator (CSM specification parameters) which proves that the CSM design meets the CSM specification. If the eventual AM design is compatible with the CSM specification, the AM should be compatible with the CSM; however, this cannot be proved at this time using the DSI simulator.

At approximately month 7½, the AM design testing is complete and an AM carrier simulator could be built and could be representative of the AM systems, however, it would be too late for CSM compatibility testing. Due to the problem of concurrent development schedules, the only area that was considered for carrier simulators was KSC.

Simulator Descriptions Matrix

Where a physical and functional simulation is identified in a single simulator, it is probably more efficient to provide a two part simulator: One part physical and one part functional.

The following notes are used on Appendix A simulator descriptions:

Note 1: The physical interface of the water receiving and storage system between the AM and CSM may be eliminated if the alternate system, presently under investigation, is adapted. This system would eliminate the CSM to AM water system umbilical by providing a fixed quantity water dispersing valve in the CM from which the astronaut would fill a flexible wall container. He would hand carry the container through the MDA and into the AM.

Note 2: The MDA will be developed, qualified, and accepted at MSFC by utilizing DSI simulators. The degree of carrier interface simulation provided by these simulators will depend on the type of subsequent test programs that will involve the MDA. If the prototype cluster test were to follow, the electrical portions of the DSI simulators required for MDA development, qualification and acceptance would be of relatively simple design due to the lack of complex subsystems within the MDA. In the simplest extreme, these simulators would only verify point to point continuity of the interconnecting cabling and operability of the few active components and experiments within the MDA.

Without the cluster test program, these DSI simulators cannot be of simple design. These simulators must represent the carrier interface to the degree necessary to determine any problems resulting from possible field coupling between wires, line loss and other electrical perturbations resulting from the operation of equipment and possibly experiments within the MDA. Basically, the DSI simulators used with the MDA must comprise a fairly close duplication of the cluster interface with both electrical and chronological simulation.

Note 3: The following experiments are listed to identify each separate interface with the MDA. Satisfaction of the requirements for simulation may be accomplished either by the use of DSI simulators or by individual experiment simulators provided by the principal investigator for the experiment involved.

Exp. No.	Types of Interfaces with MDA
M018	Mechanical only
M050	Mechanical only
M051	Mechanical only
M052	Mechanical only
M053	Mechanical only
M055	Mechanical only
M479	Mechanical, power, data mgmt, water, O_2, vacuum
M488	Mechanical, power, data mgmt, vacuum
M489	Mechanical, power, data mgmt, water, vacuum
M492	Mechanical, vacuum
M493	Mechanical, vacuum
M508	Mechanical only
M509	Mechanical only
S005	Mechanical only (launched on CSM #1)
S006	Mechanical only (launched on CSM #1)
S009	Mechanical, power, data mgmt, D&C, thermal
S018	Mechanical, humidity control
S019	Mechanical only
S063	Mechanical, time ref
S065	Mechanical, time ref (launched on CSM #1)
S069	Mechanical, power, data mgmt, D&C
S070	Mechanical, power, data mgmt, D&C, thermal
T004	Mechanical, power, data mgmt, D&C, thermal
T020	Mechanical, D&C
D018/020	Mechanical, power, data mgmt, O_2, vacuum
D019	Mechanical only
D022	Mechanical only

Note 4: The following experiments will be operated in the OWS. Simulation of the interface parameters may be satisfied by either DSI simulators or those provided by the principal investigators.

Exp. No.	Types of Interfaces with OWS (AM)
M018	Power, data mgmt
M050	Power, data mgmt, D&C
M051	Power, data mgmt
M052	Mechanical only - no simulation required
M053	Power, data mgmt
M055	Power
M439	Power
D019	Mechanical only - no simulation required
D022	Power, D&C
T020	Mechanical only - no simulation required

Note 5: Certain DSI simulator requirements identified for flights 3 and 4 may be satisfied by reworking the similar flight 1 and 2 DSI simulators. This is true for NAA requirements and portions of MSFC and KSC requirements.

Note 6: The following listed experiments are those to be performed on the ATM. Satisfaction of the requirements for simulation may be accomplished either by the use of DSI simulators or by individual experiment simulators provided by the principal investigator for the experiment involved.

Exp. No.	Type of Interface with ATM/LM
S052	Mechanical, power, D&C, thermal
S053A	Mechanical, power, D&C
S053B	Mechanical, power, D&C, thermal
S054	Mechanical, power, D&C, thermal
S055A	Mechanical, power, data mgmt, D&C, thermal
S055B	Mechanical, power, data mgmt, D&C, thermal
S055C	Mechanical, power, data mgmt, D&C, thermal
S056	Mechanical, power, data mgmt, D&C, thermal

Note 7: The following experiments are those to be reactivated during flight 3 and 4. Satisfaction of the requirements for simulation may be accomplished by the same simulators provided for flights 1 and 2 under this category.

Exp. No.	Types of Interfaces
M018	(OWS) power, data mgmt
M050	(OWS) power, data mgmt, D&C
M051	(OWS) power, data mgmt
M052	(OWS) mechanical only - no simulation required
M053	(OWS) power, data mgmt
M055	(OWS) power
M439	(CM) power
S005	(CM) mechanical only - no simulation required
S006	(CM) mechanical only - no simulation required
S015	(CM) power, thermal
S018	(MDA) mechanical only - no simulator required
S019	(MDA) mechanical only - no simulator required
S061	(CM) power, data mgmt, D&C, thermal
S063	(MDA) time reference
S065	(MDA) time reference
S069	(MDA) power, data mgmt, D&C
S070	(MDA) power, data mgmt, D&C, thermal

SIMULATOR DESCRIPTIONS

SIMULATOR ITEM NO.	USING LOCATION	TESTED CARRIER	SIMULATOR NAME	FUNCTIONAL DESCRIPTION	REF. NOTES
1	NAA	CSM	AM-DSI Simulator	Electrical - Simulate static and dynamic parameters of PCM data interface, communications system, recorders and displays and controls for power status, life support, and hazard warning. Mechanical - Duplicate external power cable connector interface and external fluids and gas umbilical interfaces. Fluids & Gas - Prototype GO_2 and GH_2 storage tanks and umbilical hoses, including throttling valves to regulate gas flow rate from sim. to CSM fuel cell storage tanks. Also includes a water receiving and storage system.	Note 1
2	NAA	CSM	MDA-DSI Simulator	Electrical - Simulate static and dynamic parameters of experiment data outputs and displays and controls for life support and hazard warning. Mechanical - Duplicate electrical connector interface and possibly fluids (water) interface, and docking collar. Fluids & Gas - None	
3	McDonnell	AM	MDA-DSI Simulator	Electrical - Simulate load characteristics of tunnel and docking lights and experiment interfaces of power, data management, and displays and controls. Mechanical - MDA non-functional structural prototype including electrical connector and gas connector interface. Fluids & Gas - Prototype cooling radiator and flexible coolant lines and connectors with shut-off valves. Also includes GO_2 interface with shut-off valve.	

SIMULATOR ITEM NO.	USING LOCATION	TESTED CARRIER	SIMULATOR NAME	FUNCTIONAL DESCRIPTION	REF. NOTES
4	McDonnell	AM	CSM-DSI Simulator	Electrical - Simulate static and dynamic parameters of PCM data interface, communications system, power source, and displays and controls for life support and hazard warning. Mechanical - Duplicate external power cable connector interface and external fluids and gas umbilical interfaces. Fluids & Gas - Prototype GO_2 and GH_2 storage tanks and umbilical hoses with shut-off valves in each gas line. Also includes prototype water storage tank with umbilical hose with shut-off valve.	Note 1
5	McDonnell	AM	S-IVB Forward Mockup (DSI Simulator)	Electrical - Simulate static and dynamic parameters of solar array and fan and light loads. Mechanical - Physical mockup of S-IVB forward section including prototype dome, hatch and boot attachment provisions.	
6	McDonnell	AM	Experiments (DSI Simulator)	Electrical - Simulate static and dynamic parameters of data outputs, loads and displays and controls. Mechanical - Duplicate electrical connector interfaces with OWS carry-in cables. Also duplicate size, shape and weight to check clearance through AM hatches, etc. Fluids & Gas - None	Note 4
7	McDonnell	AM	IU Passivation Modification (DSI Simulator)	Electrical - Simulate static and dynamic parameters of passivation command circuits and interface with passivation display and control panel in the AM. Mechanical - Duplicate electrical connector interface. Fluids & Gas - None	

SIMULATOR ITEM NO.	USING LOCATION	TESTED CARRIER	SIMULATOR NAME	FUNCTIONAL DESCRIPTION	REF. NOTES
8	MSFC	MDA	AM-DSI Simulator	Electrical - Simulate static and dynamic parameters of complete AM interface. (Same as Item #1) Mechanical - Duplicate electrical connector interface and fluids and gas interface. Fluids & Gas - Prototype thermal control system, including pump package and flexible coolant lines. Also includes GO_2 supply tank and flexible GO_2 line and connection with shut-off.	Note 2
9	MSFC	MDA	CSM-DSI Simulator	Electrical - Simulate static and dynamic parameters of complete CSM #1 and #3 interface. (Same as CSM(#1) DSI simulator plus CSM(#3) differences). Mechanical - Duplicate electrical connector interface. Fluids & Gas - None	Note 2
10	MSFC	MDA	LM A/S - DSI Simulator	Electrical - Simulate static and dynamic parameters of loads, communications, and displays and controls for life support and hazard warning. Mechanical - Duplicate electrical connector interface. Fluids & Gas - None	Note 2
11	MSFC	MDA	Experiments - DSI Simulator	Electrical - Simulation of static and dynamic parameters of loads, data outputs, and display and control interfaces for those experiments which will be operated in the MDA. Mechanical - Duplicate experiment size, shape, weight, mounting provisions, and electrical connector interface. Fluids & Gas - Simulation of the experiment interface with vacuum (space), oxygen, and water.	Note 3

SIMULATOR ITEM NO.	USING LOCATION	TESTED CARRIER	SIMULATOR NAME	FUNCTIONAL DESCRIPTION	REF. NOTES
12	MSFC	MDA	Docking Collar and Pressurization	Electrical - None Mechanical - Docking collars for all 5 ports and pressurization fittings and equipment. Fluids & Gas - None	
13	MSFC	MDA	AM Radiator Master Gauge	Mechanical - Master Gauge Plate and Pressure seal.	
14	MSFC	MDA	AM & IU Structural Mockups	Electrical - None Mechanical - AM shell structure with subsystem component size-shape mockups, IU structure with component mockups as required for fit and clearance checks.	
15	IBM	IU	S-IVB Passivation Modification (DSI Simulator)	Electrical - Simulate static and dynamic parameters of passivation display and controls and communications antenna load. Mechanical - Duplicate electrical connector interface. Fluids & Gas - None	
16			Deleted		
17	IBM	IU	AM-DSI Simulator	Electrical - Simulate static and dynamic parameters of passivation display and controls and communications system. Mechanical - Duplicate electrical connector interface. Fluids & Gas - None	
18	Douglas	S-IVB	IU-DSI Simulator	Electrical - Simulate static and dynamic parameters of passivation control program and power. Mechanical - Duplicate electrical connector interface. Fluids & Gas - None	

SIMULATOR ITEM NO.	USING LOCATION	TESTED CARRIER	SIMULATOR NAME	FUNCTIONAL DESCRIPTION	REF. NOTES
19	Douglas	S-IVB	AM-DSI Simulator	Electrical - Simulate static and dynamic parameters of passivation displays and control panels, communications, and power source. Mechanical - Duplicate carry-in electrical cables and hardware physical size, shape and mounting. Fluids & Gas - Prototype air purification supply unit and flexible air duct.	
20	Douglas	S-IVB	Experiments (DSI Simulator)	Electrical - None Mechanical - Duplicate size, shape, weight, mounting capabilities and connection to carry-in cables. Fluids & Gas - None	
21	KSC	Cluster	LM/ATM Carrier Simulator	Electrical - Duplication of LM communications system, data management system, displays and controls for ATM experiments, hazard warning and life support. Functional simulation of ATM experiments and solar array power source. Mechanical - Duplication of electrical connector interface and physical configuration of structure and docking collar. Fluids & Gas - None	
22	KSC	Cluster	IU/S-IVB Carrier Simulator	Electrical - Duplication of IU programmer and IU/S-IVB passivation modification, communication cable and antenna and OWS electrical loads including experiments. Mechanical - Duplication of electrical connector interface and IU strcture. Fluids & Gas - None	Note 4

SIMULATOR ITEM NO.	USING LOCATION	TESTED CARRIER	SIMULATOR NAME	FUNCTIONAL DESCRIPTION	REF. NOTES
23	KSC	Cluster	CSM-3 Carrier Simulator	Electrical - Duplication of CSM-3 communications system, data management system, resupply system, displays and controls for hazard warning and life support and simulation of fuel cell power source. Mechanical - Duplication of electrical connector interface, fluids and gas interface and physical configuration of structure and docking collar. Fluids & Gas - Duplication of CSM resupply system, GO_2, GH_2, and water systems.	
24	NAA	CSM (#3)	LM A/S - DSI Simulator	Electrical - Simulate static and dynamic parameters of power interface, communications, and life support, hazard warning and radiation monitor interface with CM displays and controls. Mechanical - Duplicate electrical connector interface. Fluids & Gas - None	
25	NAA	CSM (#3)	AM - DSI Simulator	Electrical - Simulate static and dynamic parameters of PCM data interface, communications system, recorders, and displays and controls for power status, life support, hazard warning and radiation monitor. Mechanical - Duplicate external power cable connector interface and external fluids and gas umbilical interface. Fluids & Gas - Prototype water receiving and storage system, and GO_2 and GN_2 storage tanks.	Note 5
26	NAA	CSM (#3)	MDA - DSI Simulator	Electrical - Simulate the feed-through and distribution characteristics of the MDA which affect the CSM interface. Mechanical - Duplicate electrical connector interface and docking collar. Fluids & Gas - None	

SIMULATOR ITEM NO.	USING LOCATION	TESTED CARRIER	SIMULATOR NAME	FUNCTIONAL DESCRIPTION	REF. NOTES
27	NAA	CSM (#3)	Experiment - DSI Simulator	Electrical - Simulate experiment power loads reflected through distribution systems to the CSM fuel cells. Also, simulate experiment S027 interfaces with CSM of power, data management, time reference and thermal. Mechanical - Duplicate electrical connector and mechanical mounting interfaces of experiment S027. Fluids & Gas - None	
28	Grumman	LM A/S	ATM - DSI Simulator	Electrical - Simulate static and dynamic parameters of solar array power source, ATM experiment interface with LM displays and controls, guidance and control interface, ECS electronics, and communications antenna. Mechanical - Duplicate electrical connector interface. Fluids & Gas - None	Note 6
29	Grumman	LM A/S	CSM - DSI Simulator	Electrical - Simulate static and dynamic parameters of power interface, communications, and displays and controls for life support, hazard warning, and radiation monitor. Mechanical - Duplicate electrical connector interface and simulate forward section of CM. Fluids & Gas - None	
30	Grumman	LM A/S	MDA - DSI Simulator	Electrical - Simulate feed-through and distribution characteristics of the MDA which affect the LM interface. Mechanical - Duplicate the electrical connector interface, docking collar and aids. Fluids & Gas - None	

SIMULATOR ITEM NO.	USING LOCATION	TESTED CARRIER	SIMULATOR NAME	FUNCTIONAL DESCRIPTION	REF. NOTES
31	Grumman	LM A/S	AM - DSI Simulator	Electrical - Simulate static and dynamic parameters of power loads and communications systems. Mechanical - None Fluids & Gas - None	
32	Grumman	LM A/S	Rack Partial Mockup	Electrical - None Mechanical - Simulate ATM rack physical structure with attachment provisions and size/shape of critical (clearance) interface areas. Fluids & Gas - None	
39	IBM	IU/S027 Exp	CM - DSI Simulator	Electrical - Simulate static and dynamic parameters of display and controls for S027 experiment including characteristics of interconnecting cabling. Mechanical - Duplicate electrical connector interface. Fluids & Gas - None	
33	MSFC	ATM	Solar Array Simulator	Electrical - Simulate static and dynamic parameters of solar array power source. Mechanical - Duplicate electrical connector interface. Fluids & Gas - None	
34	MSFC	ATM	S-IVB Partial Mockup	Electrical - None Mechanical - Physical mockup of S-IVB forward section including prototype dome and IU attachment provisions. Fluids & Gas - None	

SIMULATOR ITEM NO.	USING LOCATION	TESTED CARRIER	SIMULATOR NAME	FUNCTIONAL DESCRIPTION	REF. NOTES
35	MSFC	ATM	LM A/S - DSI Simulator	Electrical - Simulate static and dynamic parameters of displays and controls, communications, power feed through, and guidance control interface, and data management. Mechanical - Duplicate electrical connector interfaces and fluids and gas interface. Fluids & Gas - None	
36	MSFC	ATM	ATM Experiments Simulators	Electrical - Simulate static and dynamic parameters of the ATM experiments interfaces of power, data management, and display and control. Mechanical - Duplicate size, shape, mounting provisions, and electrical connector interface. Fluids & Gas - None	Note 6
37	MSFC	ATM	LM A/S Partial Mockup	Electrical - None Mechanical - Simulate physical parameters of LM A/S structure including attachment provisions and size/shape mockup of critical (clearance) interface areas. Fluids & Gas - None	
38	MSFC	ATM	Component and Experiment Mass Properties Simulator	Electrical - None Mechanical - Duplicate size/shape, weight, CG and mounting interface of components and experiments. Fluids & Gas - None	
40	Off-Site	ATM	LM A/S Thermal Simulator	Electrical - None Mechanical - Simulate thermal characteristics of the LM A/S required for thermal vacuum tests of the ATM. Fluids & Gas - None	

SIMULATOR ITEM NO.	USING LOCATION	TESTED CARRIER	SIMULATOR NAME	FUNCTIONAL DESCRIPTION	REF. NOTES
41	Off-Site	ATM	LM A/S DSI Simulator	Electrical - Same as Item No. 13. Mechanical - Same as Item No. 13. Fluids & Gas - None	
42	Off-Site	ATM	Solar Array Simulator	Electrical - None Mechanical - Duplicate size, shape and mounting provisions and thermal characteristics. Fluids & Gas - None	
43	Off-Site	ATM	Components and Experiment Thermal Simulator	Electrical - None Mechanical - Simulate thermal characteristics of the ATM mounted experiments required for thermal vacuum tests of the ATM. Fluids & Gas - None	
44	KSC	Cluster	MDA - Carrier Simulator	Electrical - Duplication of distribution system loads, life support and hazard warnings and feed-through characteristics. Mechanical - Duplicate electrical connector interface. Fluids & Gas - None	
45	KSC	Cluster	AM - Carrier Simulator	Electrical - Duplicate data management system, communications systems, recorders, displays and controls, power distribution system and miscellaneous loads. Mechanical - Duplicate external umbilical interfaces and fluids and gas interfaces. Fluids & Gas - Prototype water receiving and storage system, and GO_2 and GN_2 storage tanks.	
46	KSC	Cluster	Experiments Simulator	Electrical - Simulate static and dynamic parameters of loads, data outputs, and display and control interfaces for those experiments which will be operated in Flights 3 and 4. Mechanical - None Fluids & Gas - None	

APPENDIX B

CARRIER FUNCTIONAL INTERFACE

The following sheets summarize the major carrier interfaces and illustrate the complexity of the various cluster systems created by the functional mating of the carriers.

The sheets are arranged by systems - power, display and control, data management, communications and antenna systems.

Each sheet identifies the interfaces for that system. The number after each interface defines the number of functions and does not necessarily indicate total number of wires. In many cases the functions are carried by redundant wires for increased reliability and load carrying capacity.

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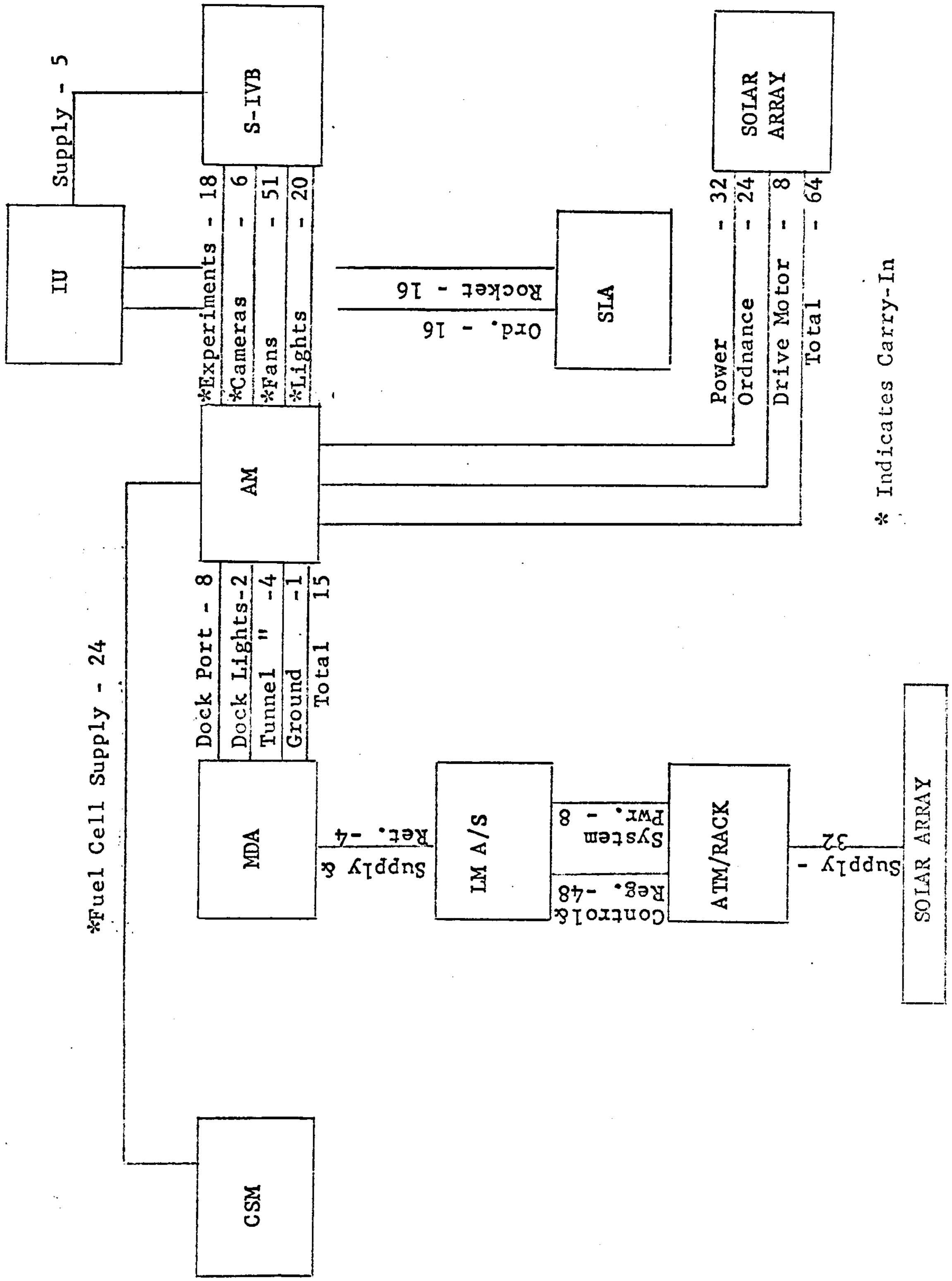

Figure B-1. Cluster Power System Interfaces

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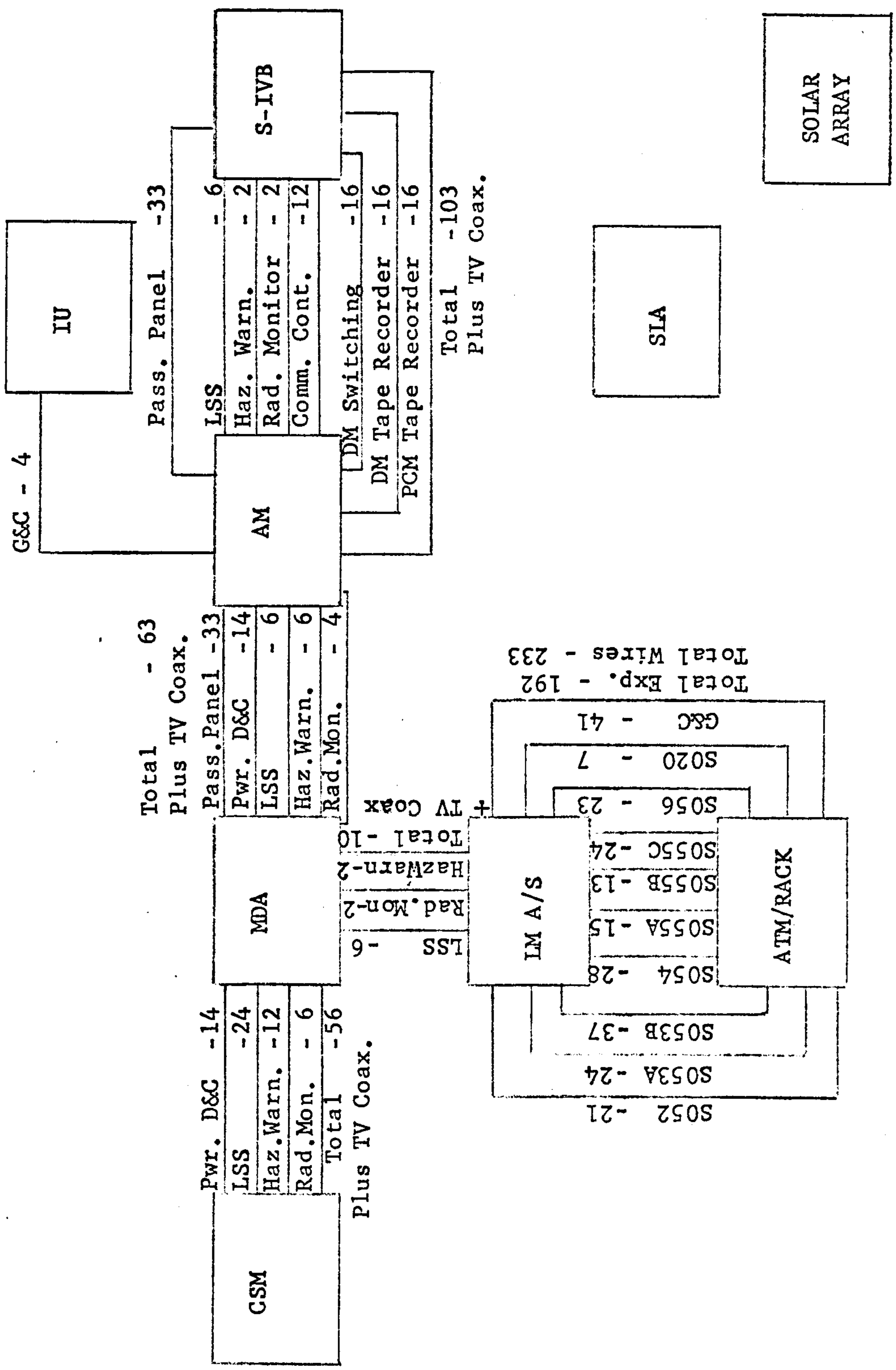

Figure B-2. Cluster Display and Control Interfaces

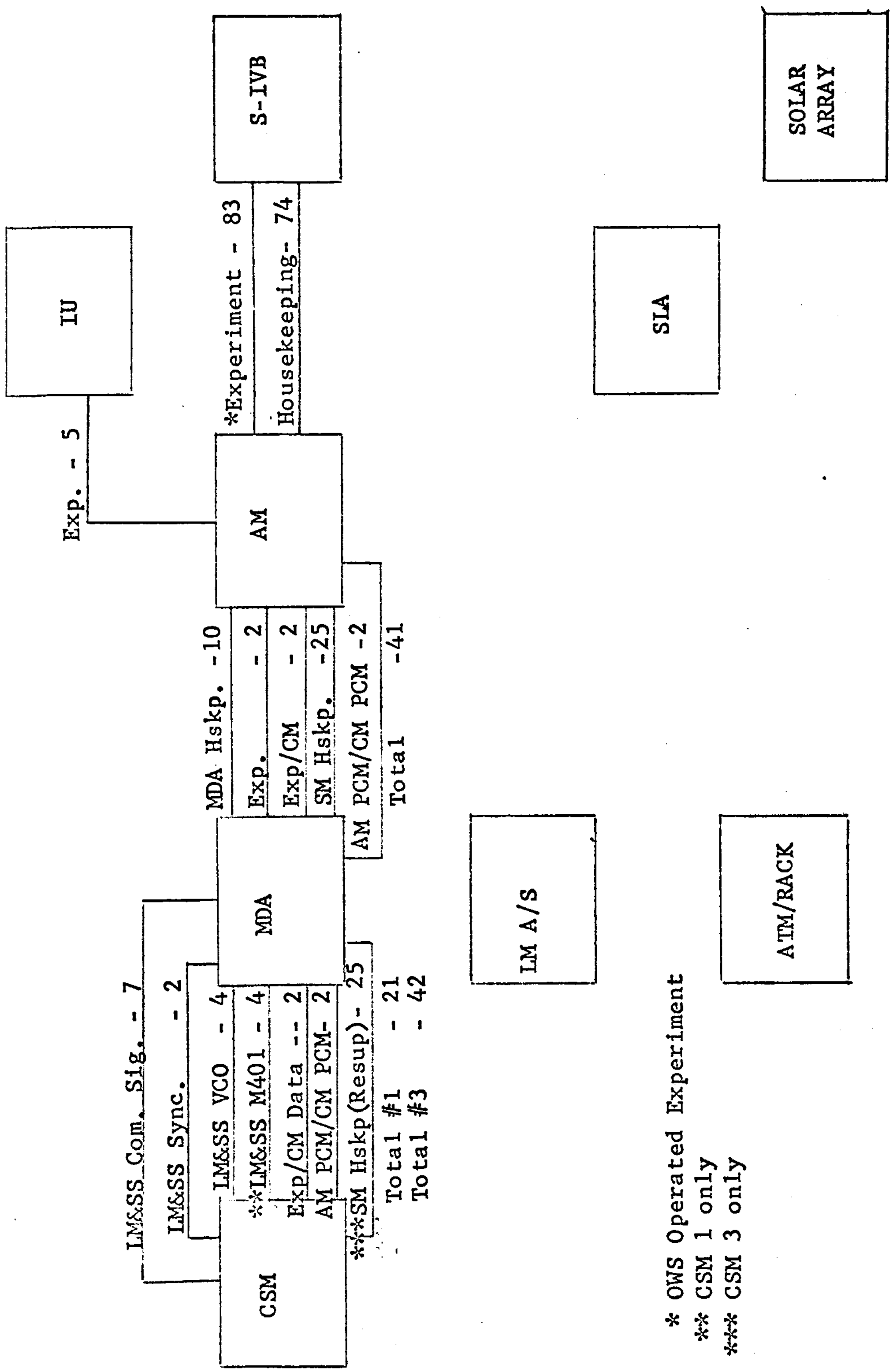

Figure B-3. Cluster System Interfaces

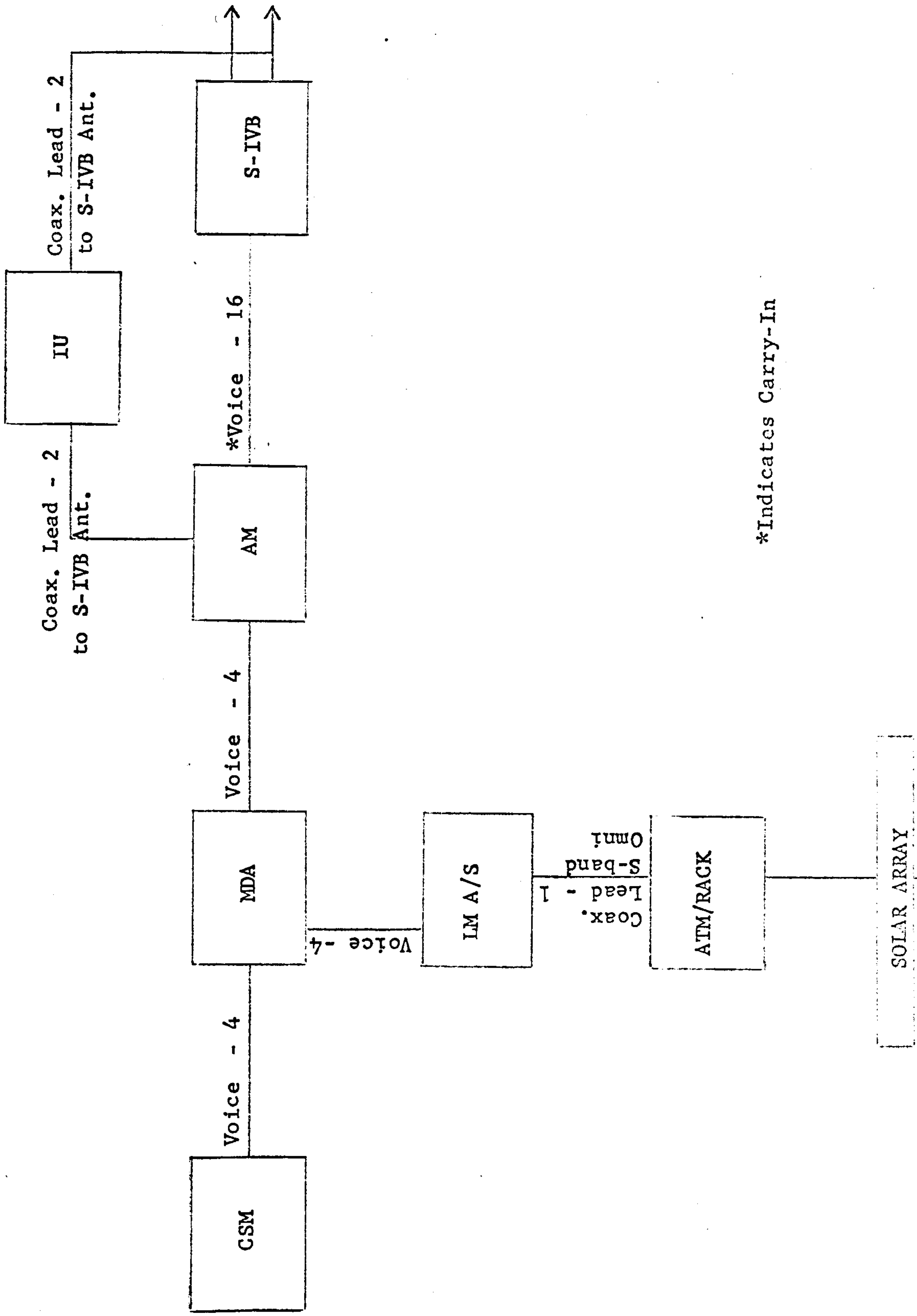

Figure B-4. Cluster Communications System Interfaces

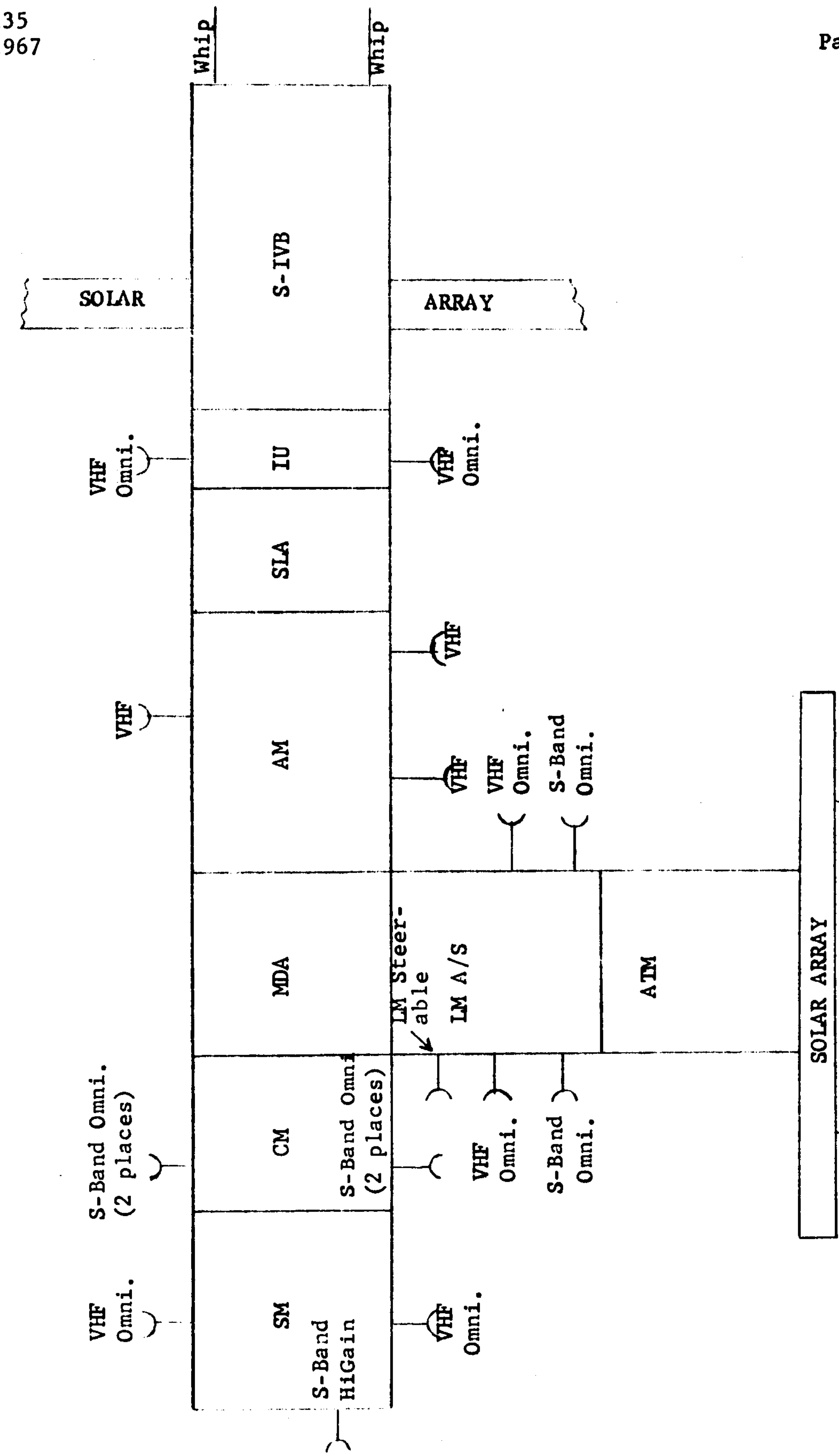

Figure B-5. Cluster Antenna Locations